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ENERGYE AND ENVIRONMENT

I.N.STAMENOV

Abstract. *Energy production and environmental consequences are the border topics in frame of the satisfaction of the energy needs of the society and their use. The present paper discusses only the energy sources and the correspondent processes to obtain energy and mainly electricity. The human health and all elements of the environment are studied in connection with some waste production or their influences.*

Nevertheless the main energy source for our Earth is the Sun and the exotic processes connected with energy production as well their spatial influence to the Earth are not taken into account. The terrestrial energy is only partly analyzed and hazards excluded.

The basic information used are based on publications of IAE, NRA, and the position paper of NPB of EPS[1].

1. INTRODUCTION

The satisfaction of the energy needs all the citizens became et present a very important condition for the positive or acceptable estimation of the quality of life. This is now the basic condition and guarantee for social freedom and worldwide prosperity. Usually this complex of conditions is understood as basis for the sustainable development, providing a solid basis for satisfaction of the needs of the present and future generations. [1] This situation requires precise analysis of the consequence of each possible energy fuel their wastes after reproduction (fig.1) shows the large scale primary energy sources devoted to total production of primary energy: NPP (31%) Coal fired P.S. 20.4%, Natural gas 18.9%, Hydropower 10.6% Lignite fired 9.1%, OIL FIRED PS 4,5%; Biomass fired [2,1 Wind turbines 1.8%, other power products 1,5%. [2] Primary sources fuel satisfied the need for concentration energy for industry, transportation and private home uses. For the main of the uses the small scale energy production is preferable. From Fig.1it becomes clear, that the nuclear energy provides an essential part of the of the world energy consummation at the present time.

The next essential energy provider is the combustion of fossil fuels, hard cool, crude oil obligatory accompanied with CO_2 emissions, which are 75% of the anthropogenic greenhouse effect. Towards to push down the contribution of anthropogenic greenhouse effect it becomes important to reduce the influence of: methane (CH_4) 13%, nitrous oxide N_2O (6%). The largest effect wherever of the reduction of CO2 is the generation of electricity in the transport sector and in economic uses by serving of energy.

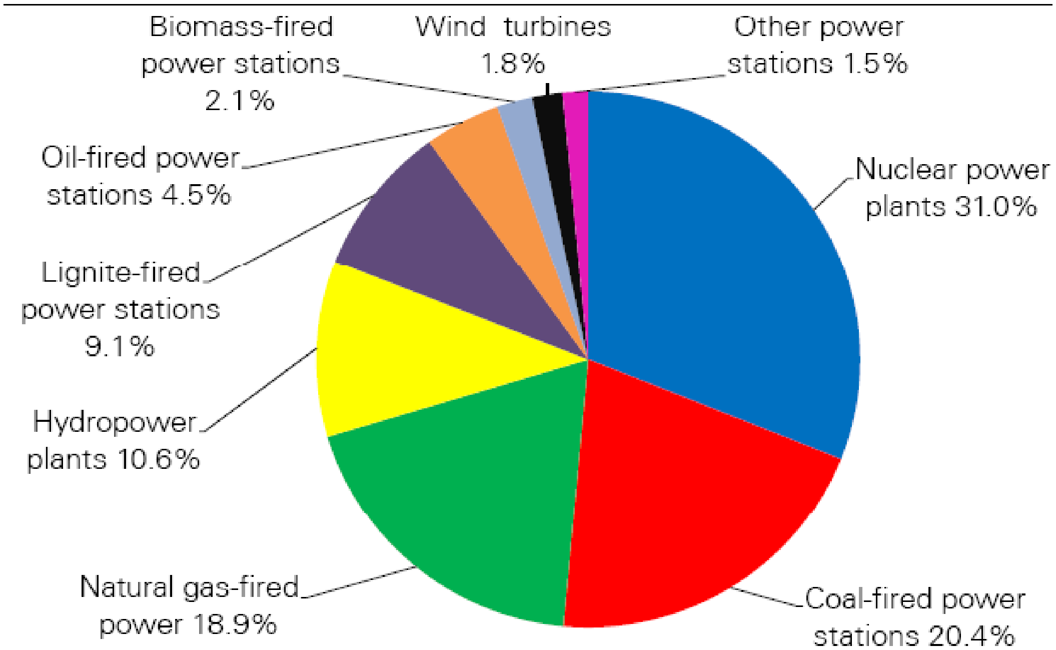

Fig. 1. Electricity generation by fuel used in power stations, EU-25, 2004

The production of electrical energy from nuclear, hydro-, biomass, wind turbines (1.5%) from geothermal (0.2%), the contribution of photovoltaic is negligible. No one of this sources emitted CO2 during its operation. Nevertheless, the rest of the primary energy sources, shown on fig.1, emit in totality 52.9% of the electric energy production.

Summarizing the situation, it is well seen that the main part of the European electricity supply is in the stabile base load or at peak loads. Reduction the nuclear power electricity supply will cause a serious lack of electricity in Europe, but in the same time all sources of electric required to be built quite sophisticated technically plants, involving extraction, processing, conversation and transportation, contributing themselves to CO2 emission. Together they form the upstream and downstream fuel cycle. In the case of Nuclear Power Plants (NPP) the retention of sulfur dioxide SO2, un burnt Carbon and in ideal case the storage of CO2 [3] to avoid emission in the atmosphere. However the technique of long term storage are not enough known.

The decommissioning of a power plant is a part from down stream Fuel cycle. In the same time both up- and down Stream fuel cycles involved CO_2-emission. However, the process of electricity generation could be only discussed in the case of the whole life cycle. The amount of CO_2 emitted for 1 kWh of electric energy produced, sometimes called the “carbon footprint”, can be calculated as a by-product of life-cycle analyses [4].

In this connection according to the Global Emission Model for Integrated Systems of the German Oko institute [4] a power plant burning coal still emits 29-37 times more CO_2 than a NPP. The conclusion following is that the nuclear electricity power generation 31% of 3,2 PWh avoids emission of 990-1270 tons of CO_2 every year. The renewable energy sources all together (14,7% of 3,2 PWh) save less of the half. The nuclear saving is more than the 704*10^6 tons CO_2 emitted by all European cars each year 4,4 Tkm [2] 1 Tkm = 1 000 000 * 1 000 000 km with 160 g/km [1]. The worldwide emission of CO_2 is about 28 billion tons [3] and would increase by 2,6 – 3,5 billion tons per year if the nuclear fuel will be replaced by fossil one. The consequence of these examples of different lifecycle analyses shows that the nuclear electricity is a negligible contributor to the greenhouse emissions and this result is independent from the institution responsible for the analysis.

2. CLIMATE CHANGE

Since of the beginning of the industrialization the world has shown a rise in average temperature due probably to the manmade application of the natural greenhouse effect by the increased emission of greenhouse gases [5]. The carbon dioxide is (fig. 2) the main contributor to the anthropogenic greenhouse gasses in the atmosphere. The carbon dioxide (ppm) [2] has increased to a level not reached before for several hundreds and thousands of years. The science is obliged to agree that the further rapid increase of CO_2 in the atmosphere will have very heavy consequences for the quality of live on the earth [5]. Following this in the Kyoto protocol [6] is agreed that the increased emission of the greenhouse gases steaming mainly from the burning of the fossil fuels must be strictly controlled.

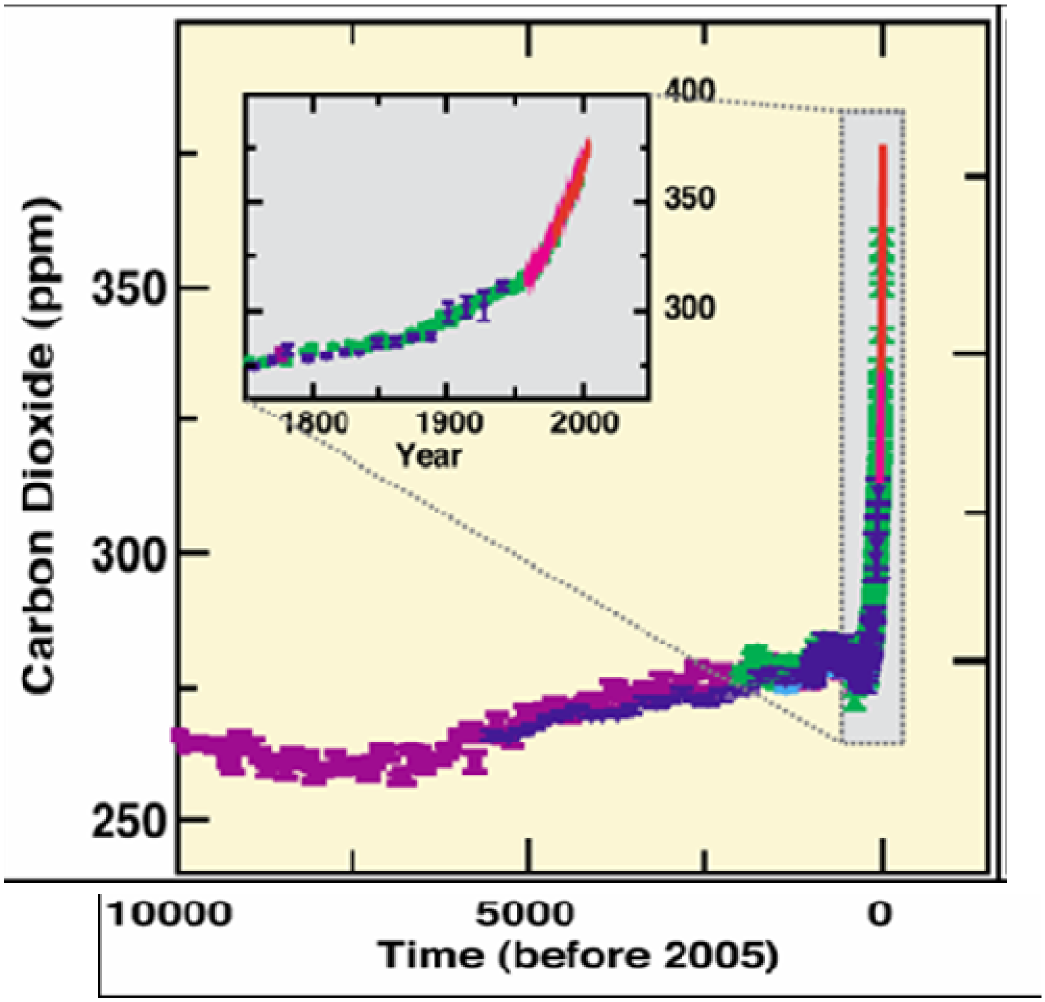

Fig. 2. CO2 concentration (parts per million, ppm) in the atmosphere during the last 10,000 years; inset panel: since 1750

3. WORLD PRIMARY ENERGY SOURCES

There are many scenarios for future of primary energy sources in development. Taking into account different starting conditions here is taken the scenario of the IEA/QECD studies [7] and shown on fig. 3 in Gtoe (1Gtoe oil equivalent – 11,63 PWh) with the world population growing from 6.5 to 8.7 billion in 2050. After 2030 fossil fuels starts to contribute less energy because adopted greenhouse gas limits. Nevertheless according to World Energy Outlook 2004 of IEA [8] both energy demand and energy related CO2 emission will increase up to 2030 and the possible rate is 1,7% per year.

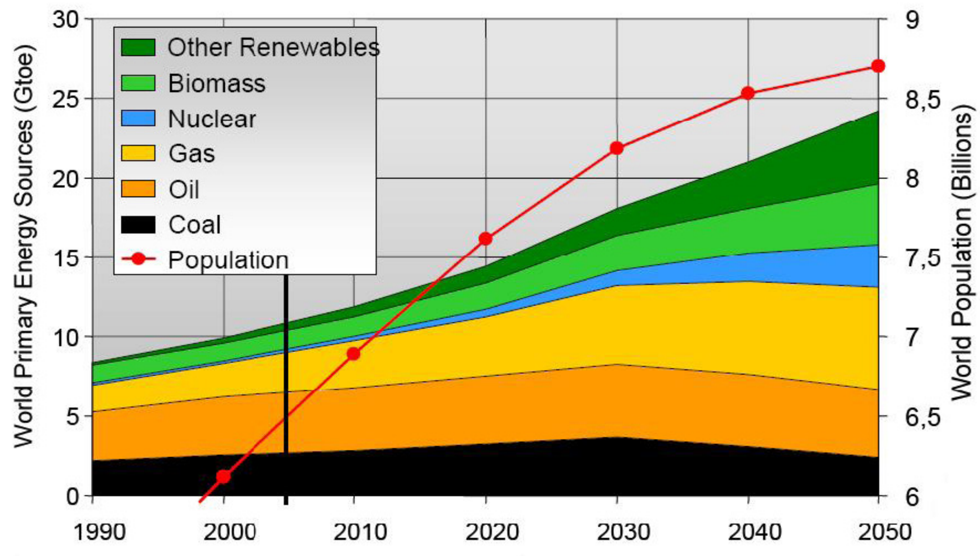

Fig. 3. Scenario of world primary energy sourcesfor a sustainable future

In the same time the main renewable source of electricity is the hydro power with a contribution which could be not essentially change for Europe [9] the same remains true and for geothermal sources. Since 1990 big windmill farms for electricity generation have been built but it is difficult to understand now how wind will replace electricity generation by gas, oil and coal (53% in total) or NPP (31%).

The most ambitious plan of EU is to reduce CO2 emissions by 20% in the period 1990-2020 mostly from transportation sector and most flat growths of photovoltaic and windmill. Taking this statement in to account the windmills have to increase by a factor of about 17 to reach the level of nuclear electricity moreover here has to be incorporated the usual 1,7% annual increase of energy demand. Additional electricity production of windmill farms and photovoltaics arise serious difficulties with the weather conditions. Moreover, that they are not effective technologies for electricity storage for acceptable time.

Analyzing the problems connected with the primary energy sources and the levels of technologies to produce electricity, the NPB of the EPS came in its position paper [1] due in December 2007 to the following **conclusions:**

1. Replacing NPP by coal burning plants is not an option because world significantly increase of CO2
2. Renewable sources will not grow fast enough to replace nuclear power in the near future.
3. In order to meet the growing demand for electricity, the choice is not nuclear or renewable sources but nuclear and renewable sources.

4. NUCLEAR POWER GENERATION NOW

Nuclear energy is already used in large scale NPP and its presently based on fission of Uranium 235 and Plutonium 239. By this way is produced about 5% of the world's total energy amount about 16% of the world electricity (2,6 PWh) [10]. At May 2004 435 nuclear power plants (NPP) are in operation. From them 196 in Europe [10] using various types of reactivity (table 1). 264 Pressured Water Reactors (PWR), 94 Boiling Water reactors (BWR), 43 Pressured Helium Water Reactors (PHWR or CANDU), 18 Gas cooled reactors (AGR@Magnox), 11 Lite Water Graphite Reactors (RBMK are in operation in Russia and Lithuania) and 4 Fast Neutron Reactors (FNR) in Japan [10]. There were declared 37 new reactor sunder construction mostly in East European and Asian countries which will produce declared power of 32 GWh. The reactor capacity of the present NPP (table 1) are technically well elaborated and this is the reason to remain in the next future with how essential upgrades mostly such connected with some life extensions. Countries like Belgium, Germany (table 1), Netherlands and Sweden are planning a gradual face outs of nuclear energy: Austria, Denmark, Ireland, Italy, Norway – the nuclear energy use is prevented by law. The situation in the Far East, South Asia and Middle East is rather different, there are about 90 reactors in operation.

Special projects are foreseen by China India, Pakistan, Japan and South Korea.

	Nuclear Electricity Generation 2006		Reactors in Operation May 2007		Reactors under Construction May 2007		Reactors Planned May 2007	
	TWh	% e	No.	MWe	No.	MWe	No.	MWe
Belgium	44.3	54	7	5728	0	0	0	0
Bulgaria	18.1	44	2	1906	0	0	2	1900
Czech Rep.	24.5	31	6	3472	0	0	0	0
Finland	22.0	28	4	2696	1	1600	0	0
France	428.7	78	59	63473	0	0	1	1630
Germany	158.7	32	17	20303	0	0	0	0
Hungary	12.5	38	4	1773	0	0	0	0
Lithuania	8.0	69	1	1185	0	0	0	0
Netherlands	3.3	3.5	1	485	0	0	0	0
Romania	5.2	9.0	1	655	1	655	0	0
Russia	144.3	16	31	21743	3	2650	8	9600
Slovakia	16.6	57	5	2064	0	0	2	840
Slovenia	5.3	40	1	696	0	0	0	0
Spain	57.4	20	8	7442	0	0	0	0
Sweden	65.1	48	10	8975	0	0	0	0
Switzerland	26.4	37	5	3220	0	0	0	0
Ukraine	84.8	48	15	13168	0	0	2	1900
UK	69.2	18	19	10982	0	0	0	0
Europe	1194.4	35.4	196	169966	5	4905	15	15870

Table 1. European nuclear power reactors.

4.1. The main conclusions for the world now are:

- NPP produce 60% of the world electricity.
- 31% of European electricity supply
- Only a few NPP construction are foreseen for Europe
- Significant expansion of NPP numbers in South Asia and in France

4.2. Risk and Safety problems

Basically the electricity production is connected with some risks. The scientific institutions developed already different procedures of risk estimations, it means the development of tools to quantify the level of the risk.

Well known risk oriented computer analysis was carried out by team of Paul Scherrer Institute, Vilingen Switzerland [11]

Another choice was undertaken by Dr B. Cohen used new quality of life expectancy. His conclusion is that the risk by the electricity generation is far less than the risks of daily life [12]. There is frequently a significant difference between the risk of a separate event and the actual chance of this event happening. The difference between small risk of major accident and large risk of minor accident remain in competition.

Radioactivity is spontaneous disintegration or transformation of atomic nuclei into another, accompanied by the emission of α, β, γ radiation. [1] The relative quantity of Th in the Earth crust is 7.2 mg/ kg crust and 2.4 mg for W. [13] The decay of both elements produces radium and radon. Natural radioactivity is found both in flora and fauna. One very impressive example is C14 which is produced by the intense flux of cosmic radiation, present on the Solar system. In the body of an average person in an age 25 and 70 kg weight 9.10^3 radioactive decays occur per second.

In the same time many countries (Germany) have regulations about the exhaust of ionizing material or emission into environment keeping these parameters under strict surveillance. The exploitation of NPP is monitored usually by governmental agencies that are authorized to shut down the plant in case of violations. However, it should be pointed out that both imission and emission is well within the spatial fluctuation of the background radiation [13]. In the same time the coal fuel power plants emit radioactive materials as coal contains 0.05-3 mg/kg uranium. Because U and its radioactive decay products cannot be retained by standard filters, they are emitted again in the environment.

Another wide discussion is the high frequency of leukemia and cancer in the regions near the NPP. The investigations of World Health Organization Geneva [14] show that this supposition is not confirmed by the facts.

The safety of nuclear power plants is often criticized because the Chernobyl accident related with a Light Water Graphite Reactor (RMBK) is type still used in Russia. In this connection we have to point out that such an accident is impossible because quite different nuclear technologies are used. Usually the new reactor generation, West and East production are constructed with high level of internal natural physical safety.

4.3. Nuclear Wastes

Yearly 10^4 tons of nuclear spent fuel are discharged from all NPP in the world. The spent fuel must either be reprocessed or isolated from the environment for hundred and thousand of years in order to prevent the biosphere. In the same time all radioactive waste nuclei will decay with the time in the stabile nuclei. However, some of waste nuclei are nuclides with high radiotoxicity such as the long lived isotopes of plutonium, minor actinides (MA) mainly americium and neptunium. The waste regulatory International Material signed by all is the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management"[15].

The handling of waste and specially spent fuel is a special area and is used to short and long term procedures. This activities are carried out since the construction of the first short spent fuel storage is usually under water towards to allow short lived radioactive nuclei to decay. Following this, spent fuel is either reprocessed so that uranium and plutonium are chemically removed and reused as reactor fuel or in the once through spent fuel cycle packed (mainly by nitrification) for future long term storage in deep under ground repositories.

The MA recovered need to be transmitted into short living fission products.

The long term exclusion of water is the main problem in the deep underground repositories.

4.4. Proliferation and extremists threat problems

Nuclear warheads are built by the nuclear powers from high enriched uranium (HEU) and from weapons grade plutonium, last time not more produced in civil NPP, but extracted from spent nuclear fuel does not have the right composition for environment and efficient warheads. The possibility to develop a nuclear weapons program depends practically only on availability of reprocessing or enrichment facilities.

The fissile material application by extremists is quite separate issue. The fissile material chemically extracted can be used to build a extremists nuclear device towards to disperse radioactive materials, moreover the safe guarded reactors will produce far less plutonium compared to the existing operating reactors. It is not to avoid that nuclear could produce nuclear weapons direct by the dismantling.

4.5. Fuel cycles

The most of operating nuclear reactors now are fission based and thermal neutron bombarded. The real process occurs for Pu-239 and U-233, which thermal reactors via neutron capture by U-238 and thorium-232. Other thermal reactors are Molten Salt Reactor and CANDU, cooled and moderated with heavy water and able to be exploited with natural uranium.

Fast reactors can even breed more fuel (PU) than they consume (fast breeder reactors). In addition to other reactor types can be distinguished with respect to their fuel cycles: the once- through cycle and the closed cycle.

Conventional uranium resources are estimated above 14,8 $.10^6$ tons. 4, $.10^6$ tones are real identified and real cost 130 USD/kg [16]. Additional 10^6 tons is an estimate given by only 43 countries, really underestimated. There are other resources from thorium and very low grade uranium. Temporary the price of uranium, thorium and others is not changing. The very large estimations show, that U ore reserves are enough for several hundred of years even if U is used in open cycle.

4.6. Open cycle

After usual mining U is converted to uranium hexafluoride UF_6, isotopically enriched to increase the concentration of fusible U235 nuclei to as rich as 4.6%.

The concentration of U^{235} in natural Uranium 0.72% is too low for use in most reaction except CANDU – type, which can run with natural Uranium.

The UF_6 is usually converted U-oxide UO_2 from which reactor fuel elements were produced, remaining up to 3-4 years in reactor after.

The spent fuel rods cannot be used for effective weapon production. This the major advantage of the open cycle regarding proliferation. The dies advantage of this process is the production of other wests, which hot to be stored hundred or thousand years.

4.7. The closed cycle

Following first approximation the same steps as in the open cycle. The main difference is that the spent fuel is chemically processed and Plutonium and Uranium are recovered cut further as (MOX) fuel used. MOX is routinely produced in La Hague (France), Mayer (Russia), Sellafield (UK), Rokkasho (Japan). In this case the MA minor advantages are the main constitutes of the large – lined radioactive waste.

An advantage of the closed fuel cycle is a much smaller demount for uranium ore.

With the present uranium supply for fission closed cycle the world wide distributed and effectively work more for more than 5000 years. Transmutation schemas, based on transmutation on Accelerator Drive System have been studied in the last decades [17].

For the future the basic idea is to use a hybrid reactor combining a fission reactor with a proton accelerator. Such hybrid system could transmute radioactive wastes into short even wastes and simultaneously produce energy. A project with the 6 FPEC will design the first experimental facility to demonstrate the feasibility of transmutation with ADS, as combination of a conceptual design and industrial level realization, with an upper time limit 2020 for effective estimation.

The ADS systems are in strong competition with Generation IV reactors designed for effective burning of MA.

4.8. Open and closed cycle nuclear reactors

Nuclear energy source is not free from hazard. The safety of NPP, disposed of waste, possible proliferation and extremist threads are all matters of serious concern. Haw far the associated risks can be considered acceptors?

4.9. Nuclear power generation in the future advanced nuclear reactors

The energy scenarios for the next 50 years show that it is necessary to keep the nuclear option for electricity generation.

The association of nuclear energy with Chernobyl and Fucushima accidents and nuclear industry has in many countries strong opposition.

The Generation III reactors [18] have been developed such as European Pressurized Reactor (EPR) presenting a further step in the nuclear safely. Improved accident control will ensure that extremely unlikely events as melt dome all radioactive material is retained inside the containment system and that consequence of such system remains to the plant itself. There will be an improved resistance once to direct impact of aircraft.

In 2001 over 100 experts from all over the world began to work on GEN IV [19] project selecting and evaluating most promising concepts with a key requirement is the exclusion of an accident like Chernobyl. An additional possibility has to be assured of using uranium – thorium cycle and reduction of radio toxicity by a factor 1000. On can be optimist to expect the first GEN V reactor operational in 2030. Moreover is relative too early to analyze the application competition ADS and GEN V [20].

4.10. Nuclear fusion reactors

A further option for nuclear energy generation is the well knows nuclear fusion process. In 2005 was taken the decision to field International Thermonuclear Reactor (ITER) [21] in Cadarache, France. In this reactor deuterium and tritium are fused to form helium – 4 and a neutron that carries 80% of the energy set free. He-4 is non-radio oxide ash of the fusion process. Once in operation, such a reactor breeds the tritium needed as fuel form lithium. The world resource of lithium is estimated ~ 12.10^6 ton.

The construction of a fusion power plant is going to use materials for which after the hard activation by neutrons, the activity decrease relativity quickly to the hands.

However, nuclear fusion might become a substantial energy supplier et the earliest in the second half of this century because technology of fusion reactors needs considerable further elaboration.

4.11. Gen IV

New reactor accepts (GEN V) will new stringed criteria for sustainability and reliability of energy production and those for safety and non-profited.

Nuclear fission and fusion have the potential to make a sustainable contribution to uncurtaining future electricity needs.

4.12. Nuclear Sector in Bulgaria

Finishing the overview of the electricity generation in Europe and in the world we are obliged to have a luck in the development of this sector in Bulgaria. The relative limited natural resources of Bulgaria and the strong willness to become modern country required and of 60 ice of the lust century the solution of the problem of electricity generation using modern technologies. The Bulgarian government decided the construction of 6 NPP of total capacity 37.6 Mw:

1970-1975 Units 1 and 2 by 40 MW PWR, standard first generation Soviet design;

1978-1982 Units 3 and 4 by 440 MW PWR, enhanced first generation Soviet design;

1982-1991 Units 5 and 6 by 1000 MW PWR, standard second generation Soviet design.

The operation of the Kozloduy NPP power units is based on the long term licenses where the scope of activities and the conditions thereof are determined.

The functional tests of the safety related structures, systems and components conducted after planed outage and during operation confirm the proper performance of the safety functions. The repair and maintenance activities as implements for assume of the equipment operation life provide for the required reliability and safety for the next fuel cycle. The equipment reliability is ensured by the non-destructive inspection program and by efficient chemical control of the primary coolant and in the secondary circuit.

The power units 1 and 2 with WWER 440 reactors belong already to since October 2010 the new State Enterprise Radioactive wastes are scheduled for decommissioning [22] in this condition the all reactors pools do not contain nuclear fuel. Preparatory actions on decommissioning were underway. The equipment for the second WWER 440 is dismantled.

The units 3 and 4 with WWER 440 reactors, which are cooled down, the nuclear fuel is withdraw from the cores and stored in the SF pools on the lower. According the operating licenses, the operation periodic tests, technical security and maintenance and supervision of the main SS is limited to the activities ensured a proper storage of the spent fuel in the SFP. The period the license validity for unit 4 is up to 26.02.2013 and the license from unit 3 was extended by NRA – on 22.05.2011 for other 3 years [22].

Units 5 and 6 are operated in compliance with the conditions of the licenses to year 2017 for unit 5 and to year 2019 are operated mainly in basic mode.

During the planed annual outage of unit 6 to toward resolve the problems with the protective of the reactor control and protection system of control rods. This activity has been accomplished. The same will be done for unit 5 during planed outage in 2012.

The reliable and safe operation of the units is confirmed by the safety indicator WANO "Number of unplanned activations of reactor scrams for 7000 h". The average value of this indicator for reactor type WWER 1000 is approximately 1 scram in 2 years.

An indicator for water chemistry efficiency is the so called chemical index, whose allowable upper limit value is 1.

According to the Regulation on procedures informing the nuclear Regulatory agency for events in nuclear facilities and sites with sources of ionizing radiation in year 2011 in total NPP Kozloduy reported 7 events: 6 events related to units 5 and 6, 1 with № 4 [22]. There is no event evaluated higher than of level 6, according INES.

Keeping so high level of exploitation safety NPP Kozloduy has during the years essential contribution to the NET electricity generation in Bulgaria.

This exploitation results are obtained preserving high status of radiation protection in Kozloduy NPP. On fig. 4 is shown the trend and the measuring results of the annual limit dose. It is well seen that the annual limit dose within 50 msV is consequently limited each year during long time in level 2002-2011.

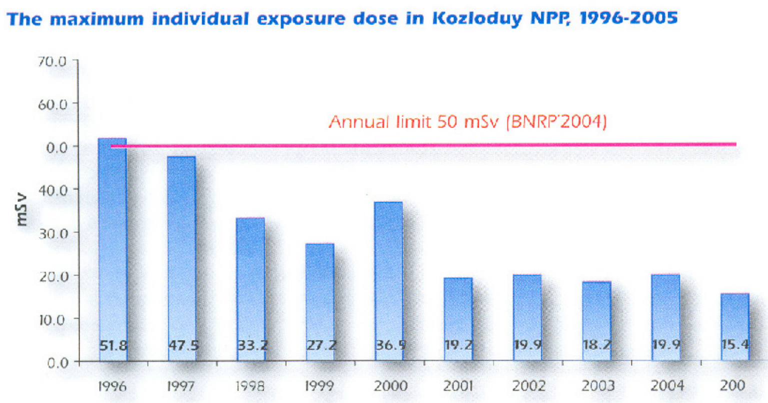

Fig. 4. The maximum individual exposure dose in Kozloduy NPP, 1996-2005

4.13. INRNE and the Reconstruction of the Experimental Reactor IRT-2000

Operating power reactors in NPP for electricity generation, which is essential part of the total energy production of the country, it is necessary to develop and keep relative high, internationally remarkable level of the nuclear science. Understanding well this situation according to the governmental decision from 2001 the existing research reactor of the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Science is in reconstruction into reactor with low level power 200 kW - IPT 200. Fig 5 show all main application fields of the reconstructed reactor, as very society important is the IE (JRC) – INRNE project BNCT channel (fig.6) connected with the reactor will be the basic for the development of a new trend in the Nuclear Medicine - Boron Neutron capture therapy, giving the possibility to treat successfully brain tumors. Around the reconstructed reactor facility was already organized Nuclear Experimental Centre with well development of: gamma spectrometry, Radioecology and Control of illicit trafficking of nuclear materials (fig.7). Towards to fulfill the reactor reconstruction the existing fresh and high enriched spent fuel hed to be retransported to Russia, using the direct financing from DoE of USA. These operations were of a big and complicated international project required finely many serious changes in different infrastructure elements of the Reactor. The retransport of the nuclear fuel elements from reactor area to Russia solves not only the local problem, but problem of the citizens from big parts of Sofia, avoiding totally the previous situation of potential danger to the spent fuel cassettes.

Fig. 5. Future utilization of the research of the reactor IRT in Sofia

The INRNE BAS is the leading complex center in Republic of Bulgaria for research in the field of nuclear science, nuclear methods and technology and their impact on environment.

Towards to realize to control in real time the impact of all this activities on environment in small and large scale parallel to the specialized local monitoring systems the Basic environmental observatory was constructed in frame of HIMONTONET and BEOBAL EC projects starting [23] thier operation on peak Moussala 2925 masl in September 1999 (fig.8). The BEO Mission is: observing, complex monitoring and studying of global change, climate, aerospace and terrestrial environment, natural hazards and technologic risks [24, 25]. The geographical position makes BEO Moussala very important for the region between Slovakia and Armenia. The detectors of the more than 25 measuring devices are placed mainly outside the building (fig. 9) towards to avoid some biases by the measurements, which are fully automatic, computer regulated, data accusation and in depended accusation system are the basic for sure data transfer (fig.10) the measuring devices in BEO permit to fulfill precise measurements and investigations in the field of Research: Complex Environmental Monitoring, Control of Long Range Radionuclides and Toxic Elements Transport, Atmospheric Physics, Atmospheric Chemistry, Sensor and Detector Development, Complex Elementary Device Design.

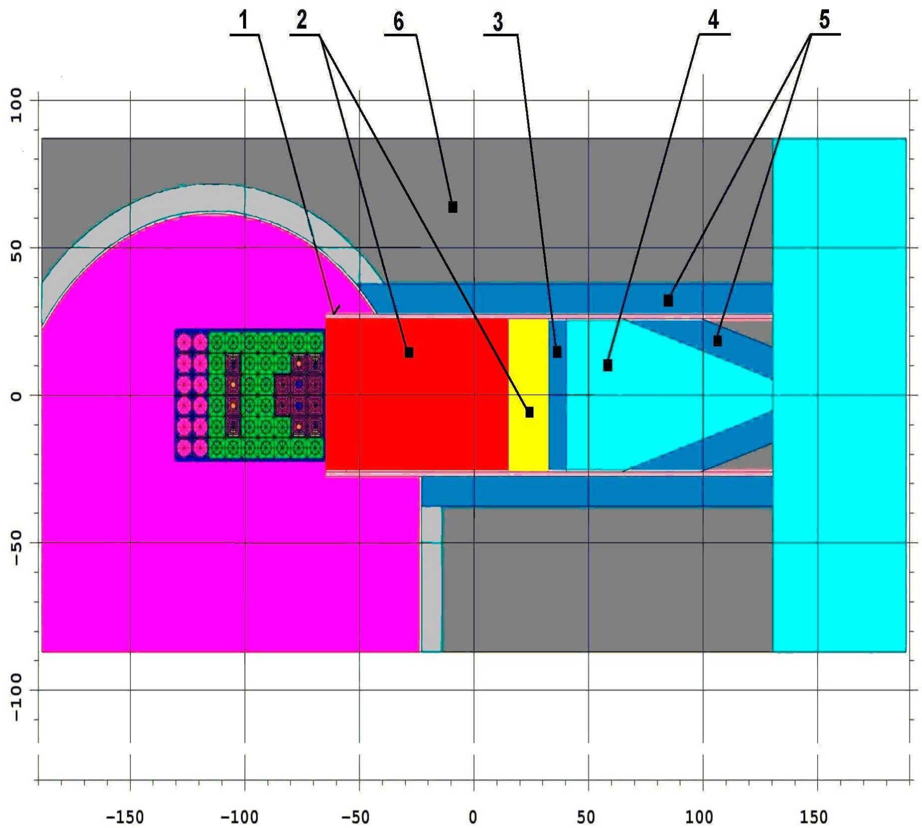

Fig. 6. BNCT Application of IRT-200

Fig. 7. International exercise in combating illicit trafficking of nuclear materials

Fig. 8. BEO Moussala

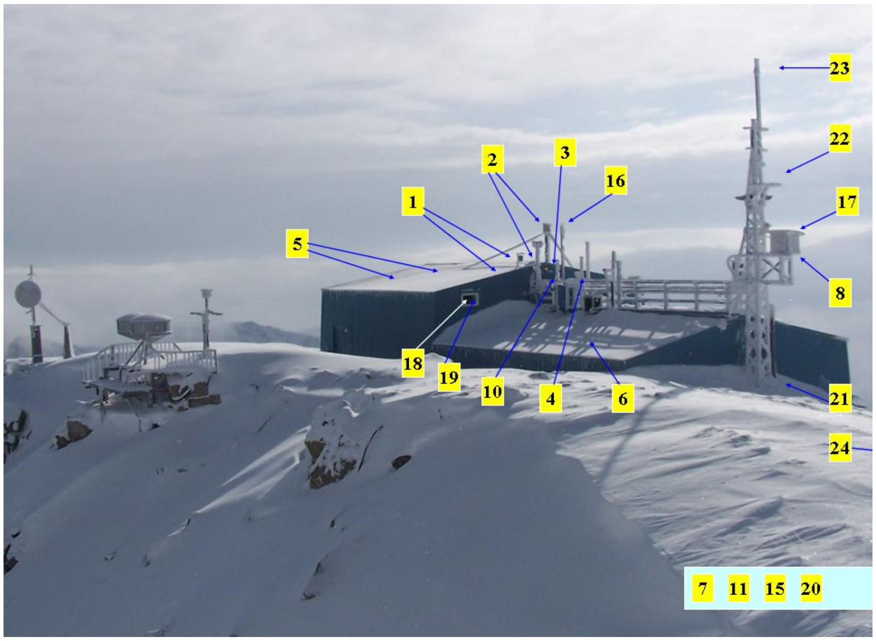

Fig. 9. Detectors positions of BEO Moussala

Fig. 10. BEO Moussala Telecommunication system

Using the created telecommunication system 35 time depends on the chosen environmental parameters could be reached and observed in internet. In real time with additional information in white and black the clouds views in 4 basic directions NSWE.

For such monitoring device system the sensibility stability of detectors, continues characters of the measure rods and the quality self-control of the registered information and its basic statistical treatment in real time is from big importance.

As example of the in real time obtained information on basic scientific fields covered by BEO Moussala it could be seen on the following figures 11 and 12:

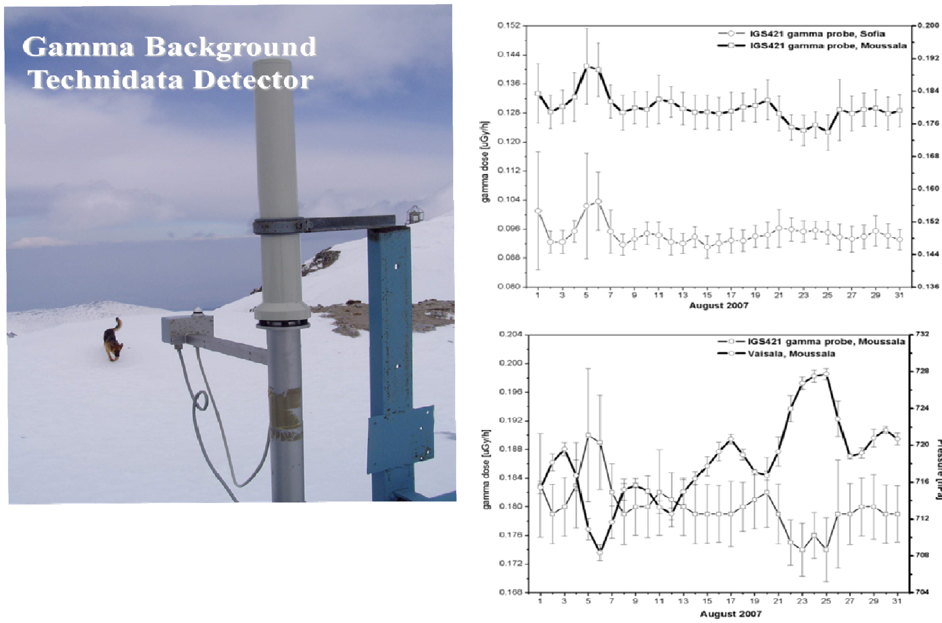

Fig.11. Gamma Background Technidata Detector

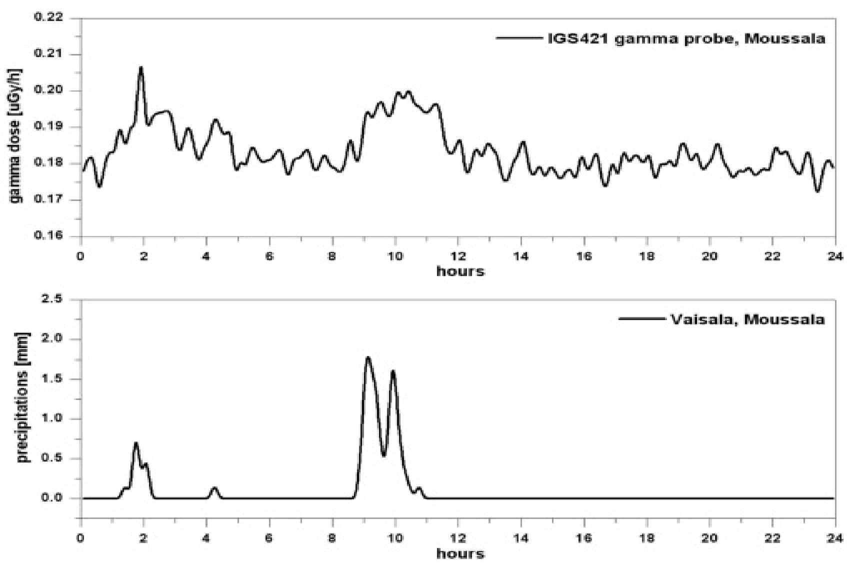

Fig. 12. Gamma Background Technidata Detector

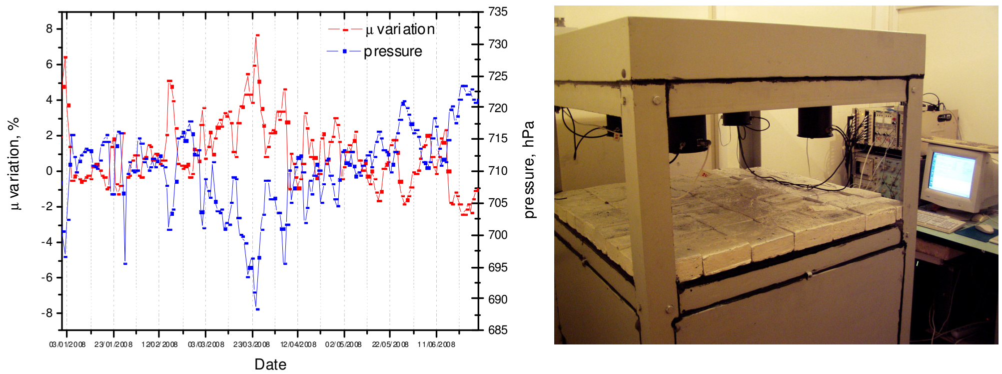

Fig. 13. Barometric effect for cosmic rays muons.

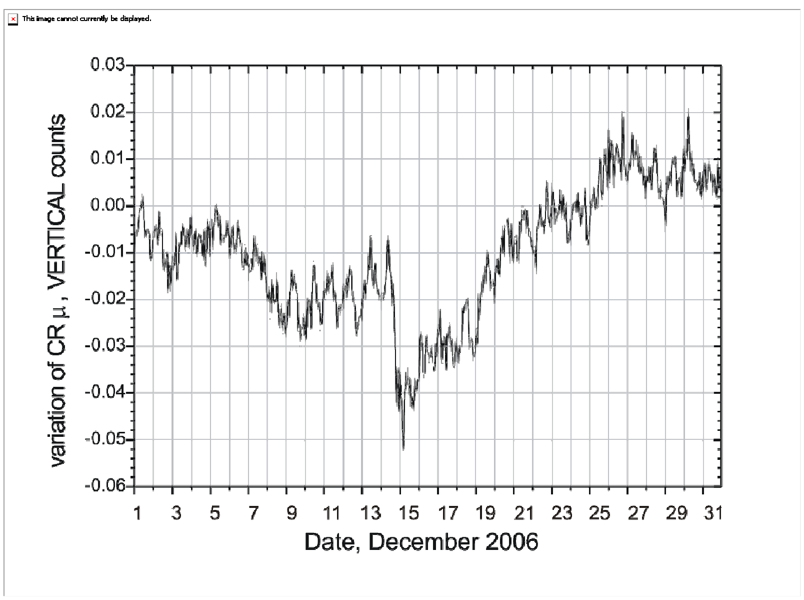

Fig. 14. The December 2006 Forbush decrease, vertical direction

– BEO muon telescope

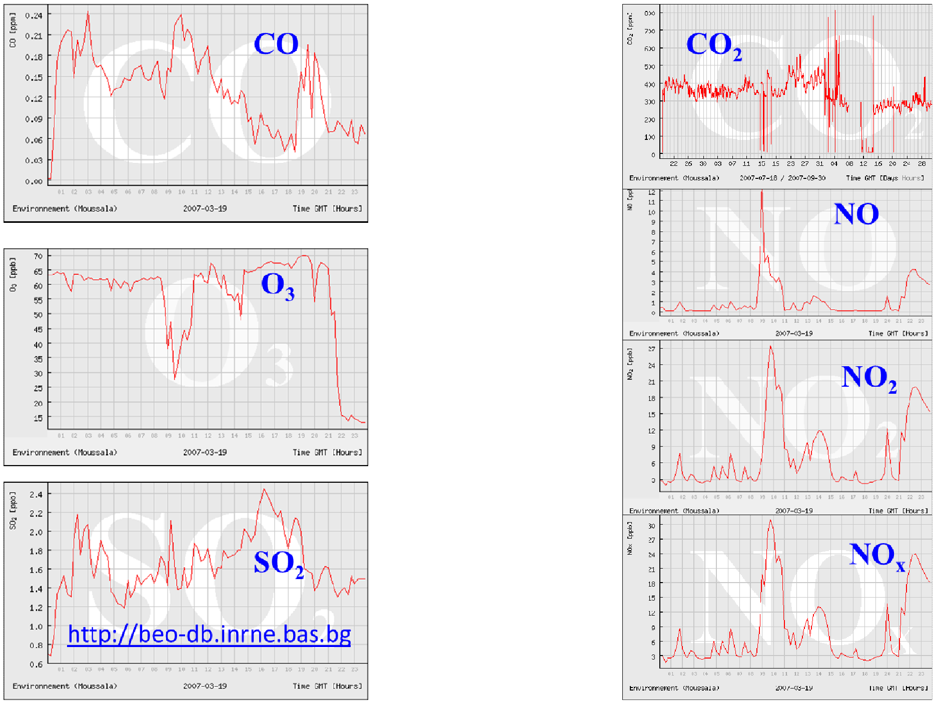

Fig. 15. Results of the atmospheric gas spectrometry.

One of the best but not last possibilities for BEO Moussala is to register the physical consequences and estimate the nature of very large scale nuclear accident consequences. On 11.03. 2011 an earthquake with magnitude 9.0 Mw stroke the East Coast of Japan. The Fokushima Daici NPP suffered heaviest consequences. The operating 3 reactors were automatically shut down. The maximum height of the waves was 14m. The site protection was only 5.7 m. The accident caused significant radioactivity release into the environment as of April 21. According Japan authorities estimate 6,3 . 10^{17} (Bq 1.31) equivalent were released, which is 10 times the less than during Chernobyl accident. Out 500 km^2 were contaminated with dose higher than 20 mSV, 80000 persons were evacuated within 20/30 km zone. Up to now there are not confirmed health effects. The effective dose for NPP shelf is 100-250 mSV.

Via EURDEP agency where Bulgaria is member and INRNE contributing member are of this Data Platform. Together with INRNE, NCRRD, EEA, Kozlodui NPP and Sofia University, radiation situation in Bulgaria was monitored.

26.03.2011 for the first time iodine 131 was detected over Bulgaria according the data from BEO Moussala within the range 90-120 µBq/m^3 was measured at peak Moussala. Opposite to this data the basic numbers for radiation protection are 7.3 Bq/m^3 also the measured values did not require any specific precautions for babies, children et all.

BEO Moussala was defined after two leading scientific inspections as a part from the Transeuropean Scientific Infrastructure what is honor for Bulgaria and in 2010 BEO became Regional Station of the Global Atmospheric Watch Program inside World Program of the World Meteorological Organization of and finally standard working facility for online measuring of the cosmic rays towards to control and study of the astrophysical aspects of the cosmic rays flux at energies $10^{12} – 10^{14}$ eV.

The BEO Moussala together with several laboratories of INRNE BAS is certified for Quality assurance Program of IGNET by certificates ISO 9001/2000 N 3312/0 , ISO 14001/2004 N 357/0.

Towards to satisfy the responsibilities to the society the scientific programs and industrial developments and solutions have to be supported by regular financing and human staff with high professional quality, motivation and sustainability.

5. LITERATURE

1. A. Freisleben, R, Johnson, O. Scholten, A. Turler, R. Wyss. "Energy for future", NPB position paper of EPS, 2007 EPS
2. Statistical office of European commission, 2006 – 2007 , ISBN 92079102/4892-2
3. H. Giepiel "Klimateshutz durh CO2 Speicherung Moghichkeiten and Risiken" (Geipel BMWA CCS 50926)
4. "Externalities of Energy" , research project of ES, www.externe.info
5. Uranion Information Centre, www.nic.com
6. Oko Inst. eV , Institute for Apllied Ecology, Freiburg , Germany.
7. Nice P.O.B. 59656 1040 LC, Amsterdam, Netherlands.
8. Parlamentary office of science and technology, October 2006, No 208
9. http:// auto.ihs.com/news/2006

10. International panel of climate change, IPCC – report 2007 WG-1, www.ipce.ch, SPM2
11. Geselschaft fur okologishe Forschung , Munhen, www.gltchenarhiv.
12. International Panel of Climate Change IPCC report 2007, WG III
13. Kyoto Protocol, http://unlccc.int.resource/docs/www
14. World Health Organisation (WHO), Geneva, news, 2005
15. www.inea.org/conventions.waste.htm
16. IAEA POB.100 A1400, Viena, www.iaea.org (news center)
17. F. Von Hippel, Plutonium and reprocessing of spent fuel science, 293, (2001) (2397-2398)
18. Posiva Oy 27160, Olkiolota, Finland www.posiva.fi
19. A technology roadmap for generation IV nuclear energy system, December 2002, www.gen-4.org/technology/roadmap
20. S. David et all, Europhysics news 2007, v.38, N2, 24
21. www.iter.org
22. Nuclear Regulatory Agency, Annual Report 2011
23. BEO Moussala series, v.1., 9.12 (1993-2000)

Study of ^{8}He nuclei via nuclear track emulsion

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Abstract: *In the paper are presented results on an investigation of ^{8}He interactions with photo-emulsion nuclei. At the ACCULINNA separator a nuclear track emulsion (NTE) is exposed to a beam of radioactive ^{8}He nuclei with energy of 60 MeV and enrichment of about 80%.*

Keywords: *radioactive nuclei, ^{8}He nuclei, fragmentation, nuclear track emulsion.*

1. INTRODUCTION

Studies of nuclei along the neutron stability border formed an area of research - the physics of nuclei with exotic structure (fig. 1). Great progress has been made in studying the structure of the nuclei ^{6}He, ^{8}He, ^{11}Li and ^{14}Be [1]. New phenomena in the structure of exotic nuclei and nuclear reactions with their participation are established. Small values of the binding energy allow us to determine the structure of exotic nuclei as a molecule-like. Evidences of their abnormally large radii are received which are interpreted as the formation of spatially separated clusters and nucleons.

The exotic nature of the structure has been established in the measurement of cross sections of interactions of relativistic nuclei with neutron excess strengthened in comparison with the geometric type dependence. However, the relativistic energy range turned out inconvenient for deeper investigations of these nuclei. For an increasing neutron excess in the study of relativistic nuclei it would be required to accelerate the increasingly heavy nuclei with large intensities. Studies of moving neutron-rich nuclei moved to the low-energy accelerators, where there are advantages for magnetic analysis and neutron detection.

In the energy range of nuclei several MeV per nucleon, there is the possibility of implantation of radioactive nuclei in a detector material. Of course, in this approach one investigates not the nucleus, but its daughter states. In this respect it is worth mentioning known, though somewhat forgotten possibilities of NTE for the detection of slow radioactive nuclei. More than half a century ago, "hammer" tracks from the decay of ^{8}Be nuclei through the first excited state 2^+ were observed in NTE, which originated in the β-decays of stopped ^{8}Li and ^{8}B fragments, in turn, produced by high energy particles [2]. Another example - this is the first observation of the ^{9}C nucleus from the decay 2α + p [3]. By using sufficiently pure secondary beams NTE appears an effective mean for the systematic study of the decay of light nuclei with excess of neutrons as well as protons. In NTE a direction and ranges of beam nuclei and slow products of their decay can be measured, which provides a basis for α-spectrometry. The primary interest is supplementing the 3α decays spectroscopy of the ^{12}N and ^{12}B nuclei [4-6] with data on 3α angular correlations.

As a first step in applying this approach in March 2012 nuclear emulsion was exposed at the Flerov Laboratory of Nuclear Reactions (JINR) ^{8}He nuclei of energy about 60 MeV.

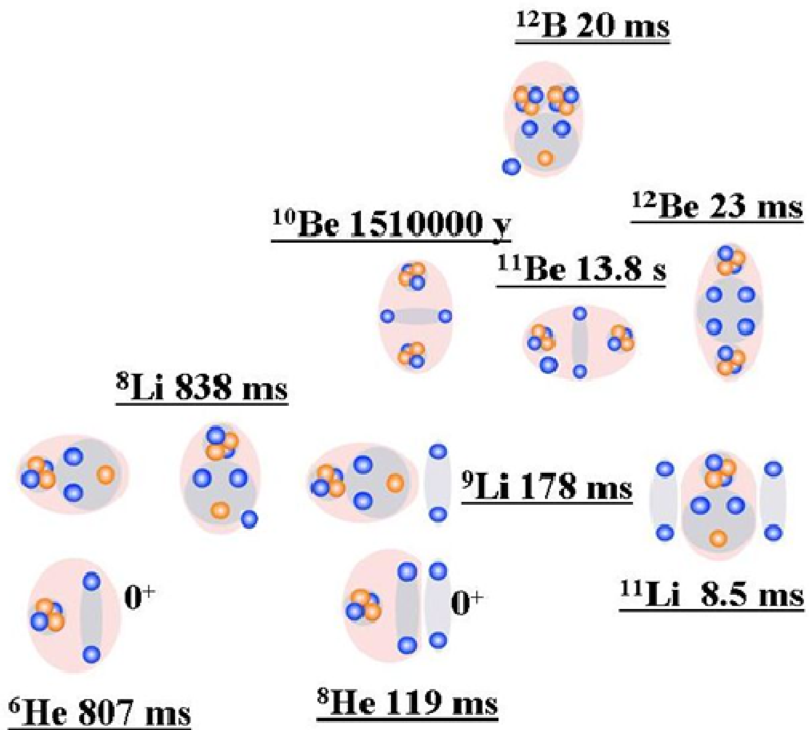

Fig. 1: Diagram of cluster degrees of freedom in stable and neutron-deficient nuclei; lifetimes of isotopes are indicated.

2. EXPERIMENT

A stack of layers of NTE was exposed on the spectrometer ACCULINNA [7, 8]. The beam in use was enriched by ^{8}He nuclei of energy about 7 A MeV. During irradiation a 107 μm thick NTE pellicle was oriented at a 10°

angle, which provided approximately 5-fold effective thickness increase. Fig. 2 shows a decay of the nucleus ^{8}He stopped in NTE. For ten minutes of irradiation statistics of about two thousands of such decays was obtained.

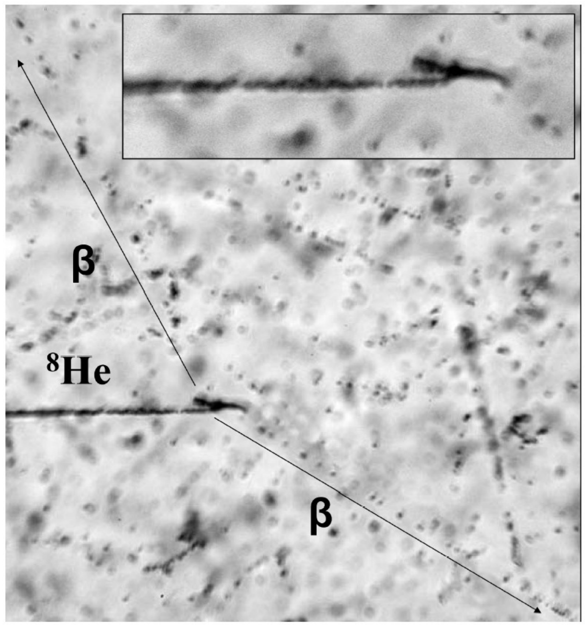

Fig. 2: Decay of a stopped ^{8}He nucleus; arrows indicate directions of emission of relativistic electrons; on insertion - magnified decay vertex with a pair of α-particle tracks (ranges of about 5 μm).

Using of an automated microscopy in searching and measuring of such decays will open the prospect of an unprecedented level of detail and statistics. One of such microscopes is PAVICOM-2 of FIAN (Moscow). The PAVICOM complex [9] was originally designed for handling of NTE exposed to Pb nuclei at the SPS accelerator (CERN). Currently, virtually all types of solid-state track detectors (emulsion x-ray film, mylar, plastic, crystals) are handled at the PAVICOM. Automatic analysis of nuclear decays seems to be the tantalizing prospect of application of the PAVICOM team experience. Then a synergistic effect of combining classical scientific culture and modern technology can be expected.

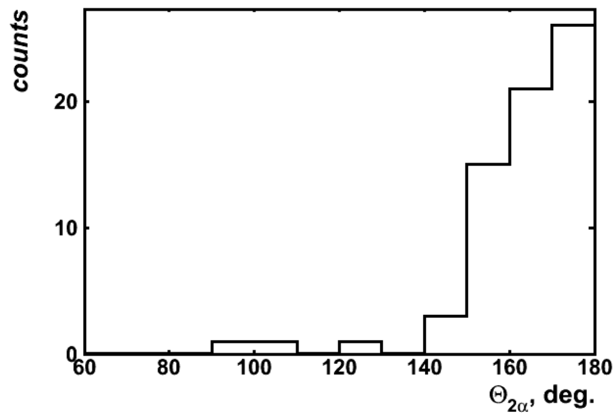

Fig. 3: Distribution of the opening angles $\Theta_{2\alpha}$ in α-particle pairs

3. RESULTS

In NTE the angular resolution for the tracks of relativistic fragments is of the order of 10^{-5} rad. The excitation energy of a fragment system Q is defined as the difference between the invariant mass of the fragmenting system M* and the mass of the primary nucleus M, i.e.

$$Q = M^* - M.$$

M* is the sum of all products of the fragment 4-momenta $P_{i,k}$ $M^{*2} = \Sigma\ (P_i\ P_k)$. 4-momenta $P_{i,k}$ are determined in the approximation of conservation of the initial momentum per nucleon by fragments.

The figure 3 shows the opening angle distribution $\Theta_{2\alpha}$ of α-particle pairs with mean value $<\Theta_{2\alpha}> = (163.4 \pm 19.8)^o$, RMS = 14.5^o. The transformation to the $Q_{2\alpha}$ (fig. 4) indicates on the identity of the source of narrow α pairs to ^{8}Be (2^+) decays with the average energy $<Q_{2\alpha}> = (3.3 \pm 0.4)$ MeV, RMS = 1.56 MeV. The observation of decay of the nucleus ^{8}Be shows a fine resolution of angle measurements as well as convenience of invariant representations. Of course, this finding is worthy of studying and testing at much higher statistics.

4. CONCLUSIONS

Thanks to its record spatial resolution and sensitivity, the method of nuclear track emulsions allowed carrying out a “tomography” for a whole family of light nuclei, including neutron deficient ones.

The nuclear photography awakens “nuclear imagination”. One cannot exclude that the completeness of the observations provided by the nuclear track emulsion may remain unattainable for the electronic detection methods. In this case, conclusions of emulsion studies will allow one to recognize their limitations and give confidence to “rich” experiments with a great variety of detectors.

The work was supported by grants from the Russian Foundation for Basic Research and by grants from the Plenipotentiaries of Bulgaria and Romania to JINR.

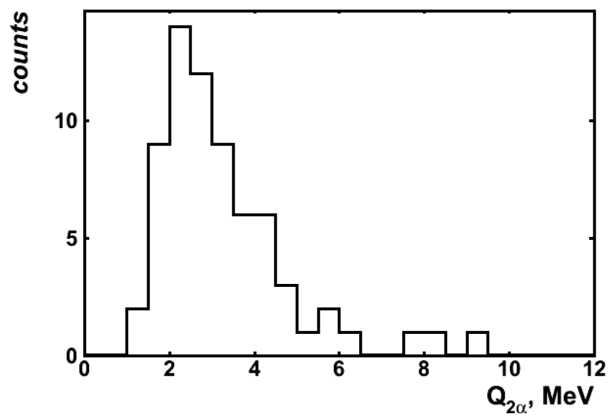

Fig. 4: Distribution of excitation energy $Q_{2\alpha}$ in α-particle pairs

5. REFERENCES

[1] Aumann, T. (2005) Reactions with fast radioactive beams of neutron-rich nuclei, Eur. Phys. J. A 26, 441-478

[2] C. F. Powell, P. H. Fowler, and D. H. Perkins, (1959) The Study of Elementary Particles by the Photographic Method, Pergamon Press

[3] M. S. Swami, J. Schneps, and W. F. Fry, (1956) Beta Decay of a C9 Nucleus, Phys. Rev. 103, 1134-1135.

[4] S. Hyldegaard et al. (2009), Precise branching ratios to unbound 12C states from 12N and 12B β-decays, Phys. Lett. B 678, 459-464

[5] S. Hyldegaard et al. (2009), Branching ratios in the β-decays of 12N and 12B, Phys.Rev.C80:044304

[6] S. Hyldegaard et al. (2010) R-matrix analysis of the β decays of 12N and 12B, Phys.Rev.C81:024303

[7] Rodin A. M. et al. (2003) Status of ACCULINNA beam line, Nucl. Instr. & Meth. B, V. 204, P. 114–118.

[8] The ACCULINNA Project http://aculina.jinr.ru/.

[9] A. B. Aleksandrov et al. (2004) Completely automated measurement facility (PAVICOM) for track-detector data processing, Nucl. Instr. & Meth. A 535, 542-545

Surface Charge Distribution for Non-Symmetrical Conducting Body

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***Abstract**: Analytical solutions for charge distribution problem for conductors are well known for ellipsoid and its degenerate forms only. In the paper an analytical solution of charge distribution on the surface of non-symmetrical conducting body is developed.*
***Key words**: electrostatics, charge distribution, conductors*

1. INTRODUCTION

The problem occurs from a problem of charge instability of conducting liquid drops that was suggested by Lord Rayleigh in 1882 0–0. The need for an analytical solution for charge distribution on the drop surface arises from search for stable forms of the drop. An analytical solution for a similar problem for solid conducting bodies is well known in a case of an ellipsoid and its degenerate forms only. In the paper, an exact analytical solution for surface charge distribution on a solid conducting body of a new non-symmetrical shape is developed.

2. SURFACE SHAPE

Let us assume q to be a known total charge of the conducting body under consideration. We consider the body to be a solid of revolution of curve $r(\theta)$ defined with the following equation

(1) $$\frac{1}{4\pi\varepsilon_0}\left(\frac{a_0}{r} \pm \frac{a_1}{r^2} P_1(\cos\theta)\right) - \varphi = 0 ,$$

where r,θ are the spherical coordinates 0, a_0, a_1, φ are certain coefficients. The surface of the body is an equipotential surface due to Poisson equation.

Equation (1) with "—" sign has the following explicit solution

(2) $$x = \frac{1 + \sqrt{1 + 4\Psi k \cos\theta}}{2\Psi},$$

where $x = r/r_0$, r_0 is a normalization parameter, Ψ is a dimensionless potential normalized to that of the conducting sphere with radius r_0, $k = a_1/(a_0 r_0)$.

The parameters should satisfy the following condition

(3) $$1 + 4\Psi k P_1(\cos\theta) \geq 0$$

The dependency $x(\theta), \theta \in (0, \pi)$ is shown in Fig. 1 at the critical values of parameters $\Psi = 1$ $k = 0.25$. If Ψ or k exceed the values the resulting surface is discontinuous. All the dependencies below are shown for the same parameter values.

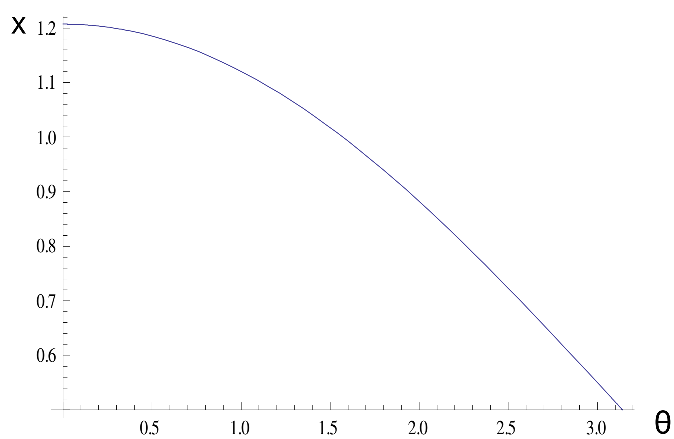

Fig. 1. The dependency of dimensionless coordinate x on azimuth angle θ.

The Oxy cross-section and 3D view of the surface shape are shown in Fig. 2 and Fig. 3

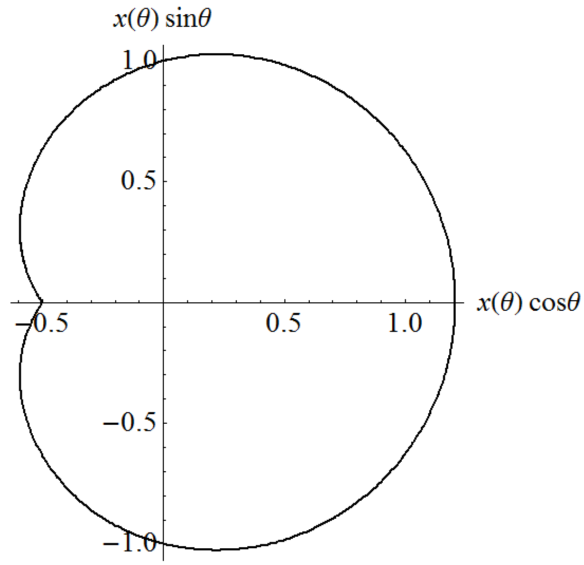

Fig. 2. The Oxy cross-section of the surface shape

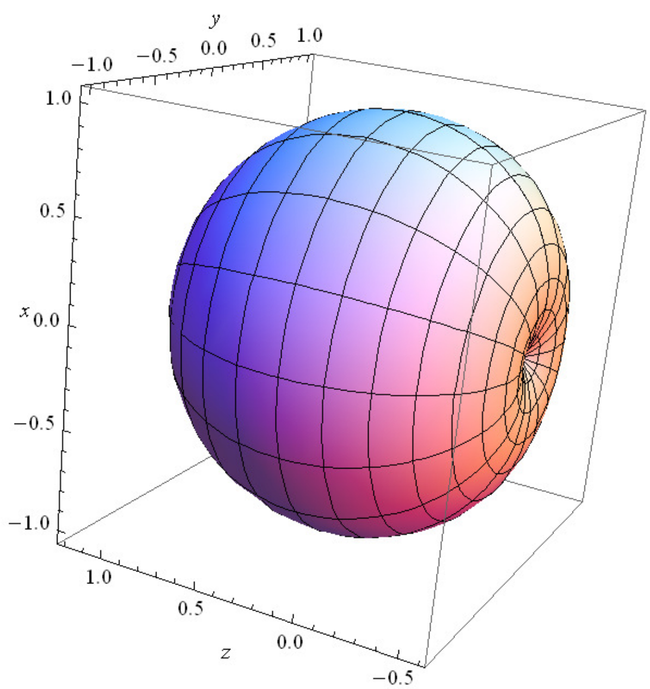

Fig. 3. The 3D view of the surface shape

3. CHARGE DISTRIBUTION ON THE SURFACE

An exact solution for the charge distribution on the surface of the body defined with equation (2) gives the following function for non-dimensional charge surface density normalized to that of the spherical body with charge q and radius r_0.

(4) $$\tilde{\sigma} = \sqrt{\frac{64\Psi^6 k^2 \sin^2\theta}{\left(1+\sqrt{1+4\Psi k\cos\theta}\right)^6} + \left(\frac{16\Psi^3 k\cos\theta}{\left(1+\sqrt{1+4\Psi k\cos\theta}\right)^3} + \frac{4\Psi^2}{\left(1+\sqrt{1+4\Psi k\cos\theta}\right)^2}\right)^2}$$

The dependency of the normalized surface charge density on azimuth angle θ is presented in Fig. 4.

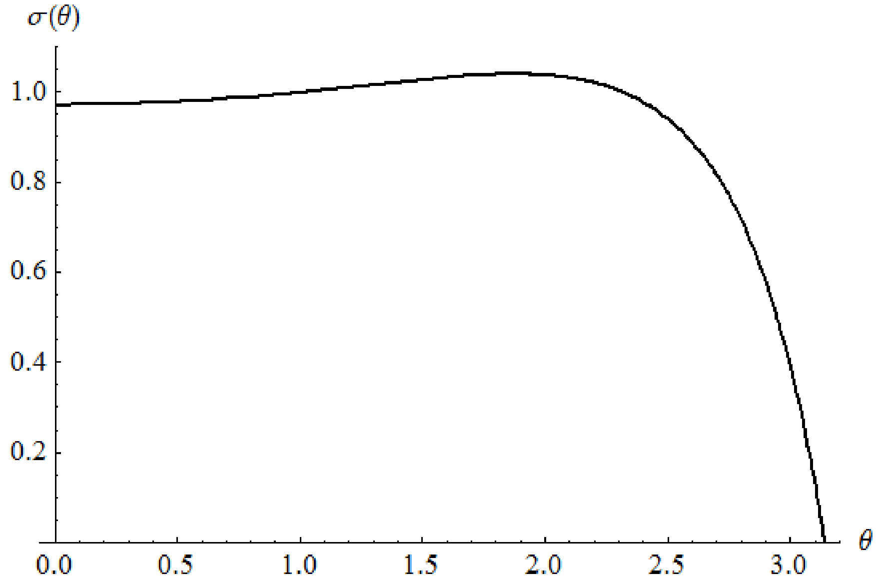

Fig. 4. The dependency of the normalized surface charge density on azimuth angle θ

The charge distribution on the surface of the body at the critical values of parameters $\Psi = 1$ $k = 0.25$ is shown in Fig. 5 and Fig. 6.

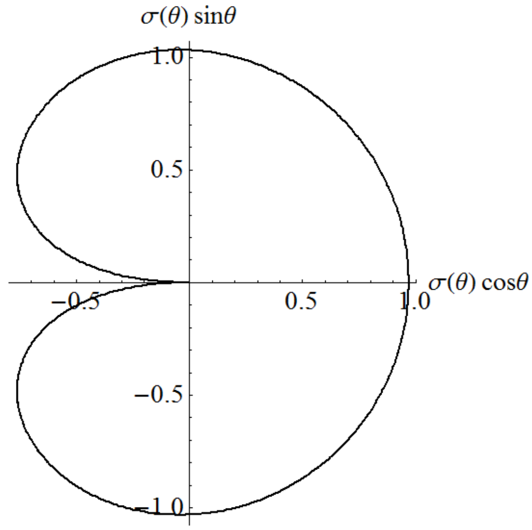

Fig. 5. The Oxy cross-section of the normalized surface charge density

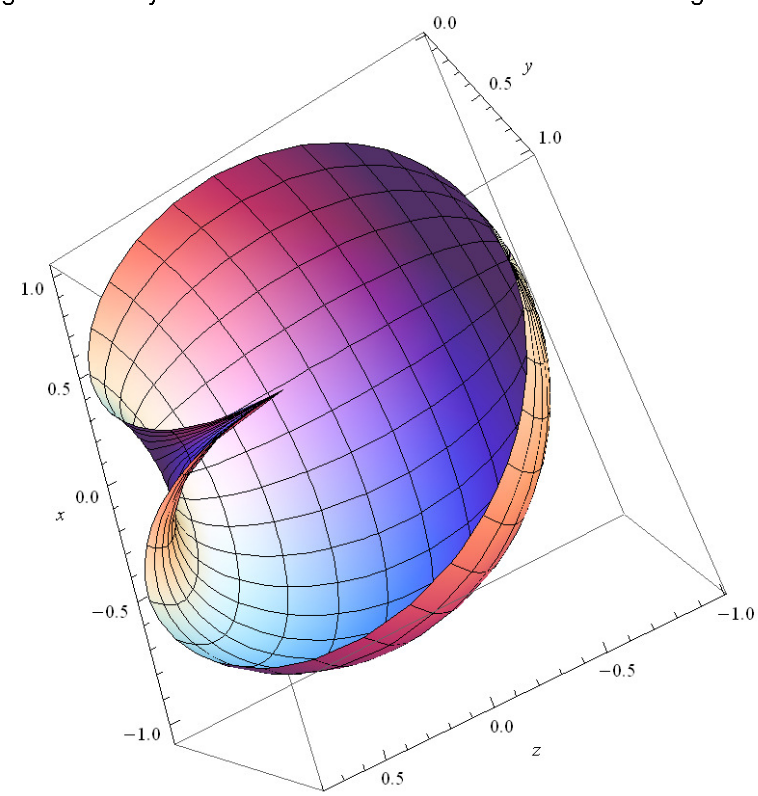

Рис. 6. The 3D view for the normalized surface charge density

If one chooses "+" sign in equation (1) the similar shape and charge distribution are obviously obtained so the deriving and the resulting dependencies of such equation are not described in the paper.

Thus the exact formula (4) for the surface charge distribution for the new shape of the conducting body was obtained with parameters Ψ and *k* being restricted to condition (3): $|\Psi k| \leq 1/4$.

4. REFERENCES

[1] Lord Rayleigh. On the equilibrium of liquid conducting masses charged with electricity // Philosophical Magazine, Ser. 5. 1882, Vol. 14. p. 184–186.

[2] Polyakov, P.A., Rusakova, N.E., Samukhina, Yu. V. (2010) *Proc. of XVIII International Conference «Electromagnetic Field and Materials»*, Russia, pp. 237-251.

[3] P.A. Polyakov, N.E. Rusakova, Yu.V. Samukhina, M.A. Tassev. Electrostatic Instability Criteria Of A Conductive Sphere With Continuous And Discrete Charge Distribution // Proc. of XIX Int.Conf. "Electromagnetic Field and Materials", 2011

[4] Polyakov, P.A., Rusakova, N.E., Samukhina, Yu. V. (2010) *Proc. of XVIII International Conference «Electromagnetic Field and Materials»*, Russia, pp.324-325

[5] Korn, G. A. and Korn, T. M. (2000) *Mathematical Handbook for Scientists and Engineers*, Second Edition, Dover, New York.

Elimination of singularities in current density distribution problems for plain conductors with sharp corners

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Abstract: *An examination of current distributions in plain conductors with sharp corners shows that nonphysical singularities appear at corner vertices. In order to eliminate them, a technique for corner rounding which involves three parameters has been developed. It allows to transform sharp angles to symmetrical arcs while preserving the analytical solution.*

Keywords*: current distribution, conformal mapping, Schwarz–Christoffel transformation.*

1. INTRODUCTION

At present, due to the miniaturization trend, engineering devices tend to use plain conductors whose thickness is much less than their linear dimensions. It is possible to describe such conductors as if they were two-dimensional. In some applications, e.g., in problems of magnetic beads control, bent conductors are used; bending provides the possibility to produce large magnetic field gradients. Obtaining measurable parameters of these conductors, whether a resistance, magnetic field, or temperature, requires calculating the current density distributions. Such calculations have been carried out both numerically and analytically [1-6].

However, each calculation method applied to conductors with sharp corners leads to the emergence of current density singularities at corner vertices [6-8]. Experimental research indicates that the current density rise actually exists at the corners but this rise is surely finite [9,10]. The emergent singularities cause significant difficulties in further calculations. When a numerical technique is used, a singularity is eliminated by some averaging over the volume of the conductor in a small area near the corner [7,8].

But this approach allows to get results being virtually arbitrary in the corners. In this paper, we have adopted a different technique. The emergence of a singularity is obviously due to the fact that we consider an ideal sharp angle non-existent in reality. Therefore, in order to eliminate these singularities we have to introduce a slight corner rounding.

2. CONFORMAL MAPPING WITH A ROUNDING

In our previous paper [5], an analytical expression for the current density distribution in a bent conductor was obtained using the Schwarz-Christoffel mapping. A technique exists for this mapping that provides the possibility to introduce a small arc rounding to the inner corners of the area considered [11]. Unfortunately, this technique only works well for arcs with a very small radius of curvature. Otherwise the arc turns to be highly asymmetrical.

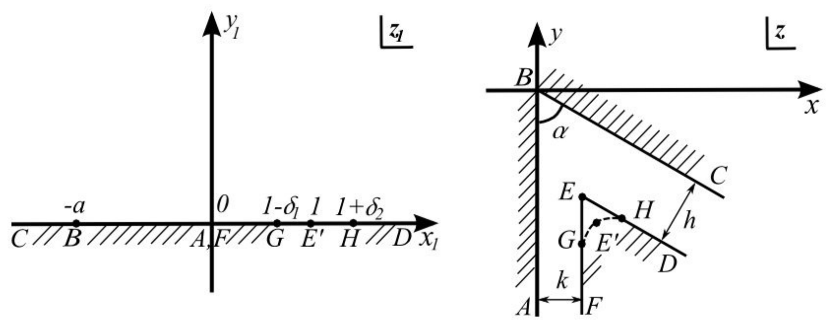

Fig. 1 The points of conformity between the upper complex half-plain and the band with a rounded corner.

In order to avoid this difficulty we have introduced one more parameter with no smallness restrictions imposed. Thus the transformation that maps the upper complex half-plain onto the bent band with a rounded corner (Fig. 1) is as follows:

$$(1)\quad z = C\int \frac{1}{z_1}\left(\frac{z_1-1}{z_1+a}\right)^{1-\beta} dz_1 + C\gamma\int \frac{1}{z_1}\left(\frac{z_1-1+\delta_1}{z_1+a}\right)^{1-\beta} dz_1 + C\gamma\int \frac{1}{z_1}\left(\frac{z_1-1-\delta_2}{z_1+a}\right)^{1-\beta} dz_1$$

$$(2)\qquad \beta = \frac{\alpha}{\pi},$$

(3) $$a = \left(\frac{h}{k} \right)^{\frac{1}{1-\beta}} \left\{ \frac{1 + \gamma(1-\delta_1)^{1-\beta} + \gamma(1+\delta_2)^{1-\beta}}{1+2\gamma} \right\}^{\frac{1}{1-\beta}},$$

(4) $$C = \frac{h}{\pi(1+2\gamma)} (\sin\alpha - i\cos\alpha).$$

Here, γ, δ_1, and δ_2 are the positive parameters that determine the shape of an arc and its curvature radius. If they tend to zero, expression (1) turns into the mapping of the upper complex half-plain onto a band with no rounding examined in [5].

We introduce the following symbol:

(5) $$I(m) \equiv C \int \frac{1}{z_1} \left(\frac{z_1 - m}{z_1 + a} \right)^{1-\beta} dz_1 ,$$

so that expression (1) turns into

(6) $$z = I(1) + \gamma I(1-\delta_1) + \gamma I(1-\delta_2) .$$

As well as in paper [5], and following the results of [12], we assume that $1-\beta = P/Q$ where $0 < P < Q$, P and Q being integers. Utilizing the following change of variables:

(7) $$t_m = \left(\frac{z_1 + a}{z_1 - m} \right)^{1/Q}, b_m = \left(\frac{a}{m} \right)^{1/Q},$$

we reduce integral (5) to a rational one:

(8) $$I(m) = -(1 + b_m^Q) QC \int \frac{t_m^{Q-1}}{t_m^P (t_m^Q + b_m^Q)(t_m^Q - 1)} dt .$$

It in turn is formally equivalent to the integral which appears in the consideration of the non-rounded case. Therefore, the following expression holds for the case of $\alpha = 60^o$:

(9)

$$I(m) = C\left\{\frac{1}{b_m^{\ 2}}\ln(t_m + b_m) - \ln(t_m - 1) - \frac{1}{2b_m^{\ 2}}\ln(t_m^{\ 2} - b_m t_m + b_m^{\ 2}) + \frac{1}{2}\ln(t_m^{\ 2} + t_m + 1) + \right.$$

$$\left. + \frac{i\sqrt{3}}{2b_m^{\ 2}}\ln\left(\frac{-2t_m + b_m - i\sqrt{3}b_m}{2t_m - b_m - i\sqrt{3}b_m}\right) + \frac{i\sqrt{3}}{2}\ln\left(\frac{-2t_m - 1 - i\sqrt{3}}{2t_m + 1 - i\sqrt{3}}\right)\right\} + C_1$$

(10) $$C_1 = -\frac{h+k}{4} - i\frac{\sqrt{3}}{12}(7k - h)\,,\ t_m = \left(\frac{z_1 + b_m^{\ 3}}{z_1 - 1}\right)^{\frac{1}{3}}.$$

By simply varying the values of γ, δ_1, and δ_2, one can obtain various rounding arcs in a relatively wide range of shapes. In practice, however, the curvature radius is important. In order to associate it with the rounding parameters, we use simple geometrical considerations (Fig. 2). The first two equations are obtained by expressing the lengths Δx and Δy through the curvature radius ρ. The last one represents the condition of equality between the distances *GE'* and *E'H* (Fig. 1).

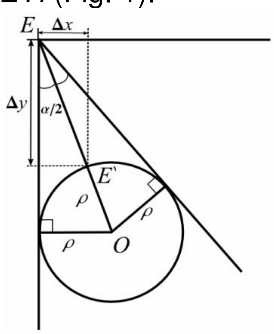

Fig. 2 Schematic representation of a rounded angle.

The resulting set of equations is as follows:

(11) $$\begin{cases} \mathrm{Re}[z(1)] = k + \rho\left(1 - \sin\dfrac{\alpha}{2}\right), \\ \mathrm{Im}[z(1)] = -\dfrac{k + h\cos\alpha}{\sin\alpha} - \rho\left(1 - \sin\dfrac{\alpha}{2}\right)\cot\dfrac{\alpha}{2}, \\ \left|z(1) - z(1-\delta_1)\right| = \left|z(1) - z(1-\delta_2)\right| \end{cases}$$

This system has to be solved numerically for each curvature radius value.

The current density is calculated the same way as described in [5]. The final expression reads:

$$j(z)=\frac{I}{k}\left|\frac{1}{C}\frac{(z_1+a)^{1-\beta}}{(z_1-1)^{1-\beta}+\gamma(z_1-1+\delta_1)^{1-\beta}+\gamma(z_1-1-\delta_2)^{1-\beta}}\right|, \tag{12}$$

where I is the strength of the current applied to the conductor. Expression (12) takes finite values all over the conductor.

The current field lines calculated for a conductor bent at an angle of 60° with dimensions k=1, h=1.5, ρ=0.05 and the dependence of the normalized current density (taken at point E', with $j_{-\infty}=I/k$ being the current density at infinity) on the rounding radius are depicted in Fig. 3.

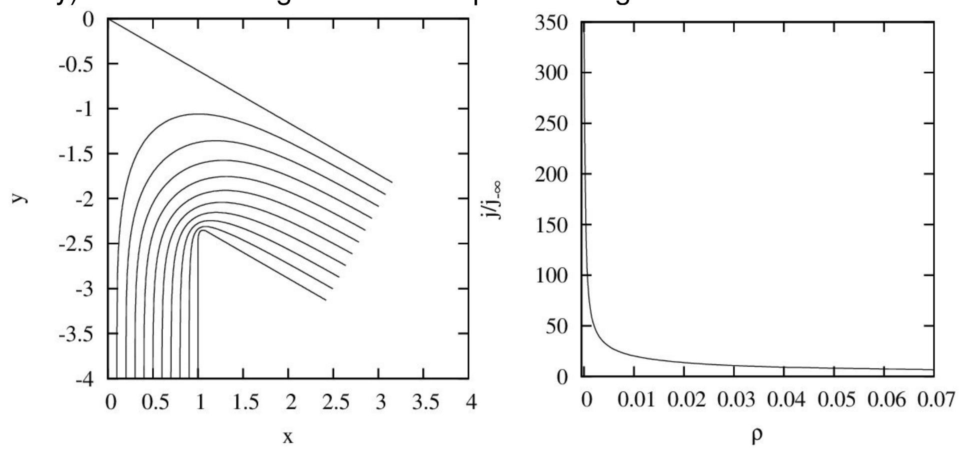

Fig. 3 The current field lines and the dependence of the current density at point E' on the rounding radius.

3. CONCLUSIONS

The technique we have developed allows to eliminate the singularities which typically emerge when considering current density distributions in plain conductors bent at sharp angles. This is done by means of rounding the inner corner. It turned out to be possible to construct a symmetrical rounding arc with radius of curvature being sufficiently large.

4. REFERENCES

[1] Trefethen L. N. (1984) Analysis and design of polygonal resistors by conformal mapping. *Zeitschrift fuer angewandte Mathematik und Physik* 35, 692–704.

[2] Hagedorn F. B., Hall P. M. (1963) Right-Angle Bends in Thin Strip Conductors. *Journal of Applyed Physics*. 34(1), 128–133.

[3] Hall P. M. (1967/68) Resistance calculations for thin film patterns. *Thin Solid Films*. 1(1), 277–295.

[4] Hall P. M. (1997) Resistance calculations for thin film rectangles. *Thin Solid Films*. 300(1-2), 256–264.

[5] P.A. Polyakov, T.N. Gerasimenko, I. Giudjenov (2011). Application of conformal mapping technique to problems of direct current distribution in thin film wires. Proceedings *of the Fourth International Scientific Conference – FMNS2011* 1, 367-372 Blagoevgrad, Bulgaria,. Faculty of Mathematics and Natural Science South-West University "Neofit Rilski"

[6] Zhang K., Gong L., Unbehauen R. (1993) Field analysis of a circular thin-film/foil resistor. *Archiv fuer Elektrotechnik* 76, 423–426.

[7] Lai Y.-S., Kao C.-L. (2006) Electrothermal coupling analysis of current crowding and Joule heating in flip-chip packages. *Microelectronics Reliability* 46, 1357–1368.

[8] Lai Y.-S., Kao C.-L.(2006) Characteristics of current crowding in flip-chip solder bumps. *Microelectronics Reliability* 46, 915–922.

[9] Choi W. J., Yeh E. C. C., Tuc K. N. (2003) Mean-time-to-failure study of flip chip solder joints on Cu/Ni(V)/Al thin-film under-bump-metallization. *J. Appl. Phys.* 94, 5665.

[10] Shao T. L., Chen Y. H., Chiu S. H., Chen C. (2004) Electromigration failure mechanisms for SnAg3.5 solder bumps on Ti/Cr-Cu/Cu and Ni(P)/Au metallization pads. *J. Appl. Phys.* 96, 4518.

[11] Lavrentiev, M. A. and Shabat, B. V. (1987) *Methods of Theory of Functions of Complex Variable*. Moscow, Russia: Nauka

[12] Kober H. (1957) *Dictionary of conformal representation*. New York, USA:Dover Publ.

Electric pulse method of rock crushing

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Abstract: *The article is concerned with methods of ragging and grinding of copper ore. The proposed electric pulse technology is one of the energetically favorable methods of ragging and grinding of natural minerals and anthropogenic raw materials. This paper presents optimal parameters in processing of the product. The results obtained by grinding of copper ore using the offered technology may be used under industrial conditions in the future.*

Keywords: *electric pulse technology, copper ore, reduction range*

1. INTRODUCTION

Copper and its alloys are widely used in construction of transmission power lines and communication devices of various types, in the electric machine industry and instrument engineering, refrigeration technology (manufacture of heat exchangers, cooling devices) and chemical engineering (manufacture of vacuum equipment, coils). Electrical industry consumes about 50% of all copper. On the basis of copper a large number of alloys with metals such as Zn, Sn, Al, Be, Ni, Mn, Pb, Ti, Ag, Au, etc., and less often with nonmetals P, S, O, etc. were composed. Application of these alloys is very extensive. Many of them have high antifriction properties. Alloys are used in cast and forged states, as well as in the form of powder items. For example, its alloys in bronze types with Tin (4-33% Sn), lead (~ 30% Pb), aluminum (5-11% Al), Silicon (4-5% Si) and antimony are widely used. Bronze is used to manufacture bearings, heat exchangers and other items in the form of sheets, rods and tubes in chemical, paper and food production industries. Alloys of copper with chromium and powder alloy with tungsten are used to manufacture electrodes and electrical contacts [1].

In chemical and engineering industries brass – an alloy of copper and zinc (up to 50% Zn), usually with the addition of small amounts of other elements (Al, Si, Ni, Mn), is also widely used. Alloys of copper and phosphorus (6-8%) are used as solders [2].

For copper production copper ore and Cu wastes and its alloys are used. Copper ores contain 1-6% of copper. Rocks containing less than

0.5% Cu are not processed, since at the current level of technology, copper extracting from it is not profitable.

Copper extracted from copper ore or underground mines, undergoes several stages of processing. The initial processing stage is ragging and crushing of the copper ore. Ragging is divided into the following types: coarse, medium and fine. At coarse ragging the ore is crushed to pieces of 100-300 mm, at medium ragging – of 30-100 mm and at fine ragging — up to 5-25 mm size.

Coarse ragging is carried out in underground conditions, and for medium and fine ragging cone crushers on the ground surface are used. After each stage of ragging the ore is sent to dry or wet grinding. Ore grinding is carried out in drum mills, drum diameter ranging from 1 to 5 m, and length – from 1 to 8 m. The ore is milled by iron or steel balls, cylinders or rods that half fill the mill and roll in the drum as it rotates around the longitudinal axis.

One of the drawbacks of mills is the wear out of balls. Therefore, for the normal operation of the mill it is necessary to maintain the optimum weight of ball load. To do this, the mill is constantly filled with new balls. In this case, the mill is mounted on a stand for repair, all the balls are unloaded from it, they are divided into classes according to sizes at a sorting installation. Small balls (10-15 mm), and those out of shape are removed, and the mill is filled with new balls of corresponding size [3, 4].

In this regard, in the laboratory of hydrodynamics and heat transfer at the chair of engineering thermophysics named after Professor Zh.S. Akylbaev in Karaganda State University named after E.A. Buketov an electric pulse plant was designed and developed. It is based on the use of pulse shock wave resulting from the spark discharge in a liquid for ragging and grinding of copper ore [5, 6, 9]. The crushing machine has a cylindrical chamber with installed linear system of electrodes. The positive electrode is placed vertically, while the negative electrode is the metal chamber bottom of hemispherical shape. A powerful electric pulse passing in the liquid medium, which is moistened ore, causes an electric breakdown, accompanied by hydraulic stroke of great destructive power. To obtain high pressures at the shock front, crushing and grinding solid fractions, the electric discharge is carried out in an aqueous solution of copper ore [7, 8].

Aqueous medium, in which the high-voltage electrical discharge takes place, is a transformer of energy, released from the discharge channel, and due to low compressibility it results in a sharp rise of pressure.

Unlike mechanical crushers, the electric pulse plant has no intensively moving parts; it is made of ordinary structural steel, so its case doesn't practically wear out at work. Main factors affecting the grinding process are the intensity of the pressure wave pulse, its duration, characteristics of energy input in the discharge channel, the total duration of the complete grinding process, high-speed fluid flows formed as a result of volume microcavitaion [10].

2. EXPERIMENTAL

At high-power pulse electric discharge, an electrohydraulic effect takes place between electrodes placed in a liquid. In this case, the rapid release of energy in the discharge channel increases the pressure in it, and its further expansion results in shockwave and fluid flow. The shock wave in the liquid is a density step, which is spread in the discharge channel faster than sound, thus, the pressure at the front of a shock wave in the liquid can reach tens of kilobars. The effect of this pressure on the processed object is restructuring the object material (crushing of brittle materials, deformation, hardening of the surface, etc.). Fluid flows, spreading at a speed of $10^2 \div 10^3$m/s, transfer the kinetic energy to the processed object, causing, like the shock wave, mechanical changes in it [11].

The research objective of ragging and grinding of copper ore was to determine the optimal value of the distance between electrodes and discharge energy at a commutation device. In the experiments, the original diameter of copper ore fractions averaged $3,5,7\,mm$.

The research work at the electric pulse plant was carried out at different values of capacitance of the capacitor bank $(C =: 0.25; 0.5; 0.75\ \mu\text{F})$, distance between electrodes at the commutation device $(l_p =: 8;\ 10;\ 12; 14\,mm)$ (Table 1), energy of discharge $(W = 60 \div 486\,J)$. The value of voltage supplied to the commutation device was regulated from $22 \cdot 10^3$ to $36 \cdot 10^3\,V$.

Figure 1 shows the results of ragging and grinding of copper ore using the electric pulse plant.

a) b)

Figure 1. Various factions of crushed ore. I – original product before processing (fraction diameter of 5 mm), II – after electric pulse processing (fraction diameter of 0.2 mm)

As Tabel 1 shows, the reduction range of the ore to the diameter up to 0.2 mm at the capacity of capacitor bank of 0.25 µF, at all values of discharge energy is very low, and with increased capacity of capacitor bank (0.5; 0.75 µF) at all values of discharge energy the reduction range of the ore increases and is approximately the same.

When solids are exposed to electric pulse in an aqueous solution, the intensity of the grinding process increases as a result of impact of additional pressure due to cavitation. Actually, at each solid particle a cavitation microcavity occurs that collapses enhancing the mechanical effect

Tabel 1: Granulometric composition of ore ground to the diameter of 0.2 mm using electric pulse technology

Reduction range of the product K% (up to the diameter of 0.2 mm), depending on the discharge energy (W) at different values of the capacitor bank (C)				
Original fraction diameter, mm	condenser capacity 0.25 µF			
	60.5 J	84.5 J	12.5 J	162 J
3	10.25	29.75	30.5	29
5	24	26.75	33.75	34.75
7	1	3.25	2	16
Original fraction diameter, mm	condenser capacity 0.5 µF			
	121 J	169 J	225 J	324 J
3	27.5	30.5	34.5	28.25
5	31	32	37.25	39.5
7	17	21.25	38	29
Original fraction diameter, mm	condenser capacity 0.75 µF			
	181.5 J	253.5 J	337.5 J	486 J
3	29	34.75	34.25	38.25
5	32	34	35.75	38
7	34	37	41	43.75

According to the obtained results, the electrode distance between electrodes of $l = 12\,mm$, at which the output was the highest, was recognized as optimal one. Further increase in electrode distance between electrodes stabilizes the output of final product output, but this changes the pulse recurrence frequency. Rise of pulse recurrence frequency results in ragging to uniform size fractions. Increase in specific energy supplied to the discharge channel, the proportion of ground fractions increases.

Taking into account the obtained optimal values of regulated parameters $(l = 12\,mm,\ C = 0.5\,\mu F,\ W = 225\,J)$ and at process duration of 5 min., the desired product – fraction of 0.2 mm diameter in the amount of 34, 37.25

and 38% from original copper ore fractions of 3, 5 and 7 mm diameter respectively, was obtained.

3. CONCLUSIONS

Thus, the obtained results showed that the proposed method of copper ore grinding makes it possible to regulate the granulometric composition of the product with high selectivity. Energy options of the plant are most appropriate in production conditions and provide intensive ragging and grinding of copper ore. The technological process of electric pulse technology can be easily automated, its maintenance does not require a large number of highly skilled workers.

4. REFERENCES

[1] Perov V.A. Ragging, grinding and screening of minerals: a textbook for higher education institutions. /V. A. Perov, E.E. Andreev, L.F. Bilenko. – M.: Nedra, 1990.

[2] Reference-book on ore processing. Concentration plants: 3rd edit. Advanced / Ed. O.S. Bogdanova, V.A. Olevsky. – M.: Nedra. 1982.

[3] Fishman M.A. "Bases of non-ferrous metal ore processing ", "Nedra", Moscow, 1968.

[4] Egorov V.L. Minerals processing. – M. Nedra, 1986.

[5] Yutkin L.A. Electrohydraulic effect and its application in industry. - Leningrad: Machine building, 1986. – 253p.

[6] Guly G.A. Scientific bases of discharge pulse technology / Electrohydraulics production design department of USSR AS. - Kiev: Naukova Dumka, 1990. - 280 p.

[7] Kurets V.I., Usov A.F., Tsukerman V.A. Electric pulse disintegration of materials. – Apatity: Kola Scientific Center of RAS, 2002. –324 p.

[8] Nusupbekov B.R., Shaimerdenova G.M. Kusainova D.K. Dynamics of destruction and formation of structures in the process of electroimpulse processing of silicium minerals. Eurasian Physical Technical Journal. – 2008. – Vol.5. – №1(9). – P24-28.

[9] Nusupbekov B.R. Obtaining nanomaterials from natural minerals using effect of Yutkin. Innovative development and relevance of science in modern Kazakhstan. Collection of articles of III International Scientific Conference. – Almaty, 2009. – P. 298-302.

[10] Nusupbekov B.R., Khasenov A.K., Nusupbekov A.N. Disintegration of metallurgical silicon by means of electric pulse discharge. Deformation and fracture of materials. – M., 2012. – № 9. – P. 37-39.

[11] Nusupbekov B.R., Khassennov A.K. Electric pulse Method of Materials Disintegration. European Researcher. – 2012. – Vol. 36.– № 12-1. – P.2118-2120.

Development of electro-hydraulic pulse technology of drilling wells for installation of heat exchange elements of heat pumps

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Abstract: *The aim of the study is to develop scientific and practical principles of implementation of energy saving heat pump technology for heat and cold supply to residential, public and industrial premises on the basis of alternative and renewable sources of energy. One of the effective methods to generate heat from groundwater by means of heat pump technology is the use of wells for consolidation of heat exchange elements produced by drilling. Fundamentally new innovative method of making wells is electro-hydraulic drilling, when electrical energy directly in the bottomhole transforms into mechanical energy of shock waves that can break up rocks. This paper describes the results of studies of the impact of electro-hydraulic pulse on hard and superhard rock minerals.*

Keywords: *heat pump, heat exchanger, well, electro-hydraulic drilling.*

1. INTRODUCTION

One of the energy efficient methods is to obtain thermal energy is a heat pump technology which makes it possible to save energy using heat of the ground, underground water, water bodies, natural water flows, etc. [1]. The environmental benefit from the use of this technology is that it enables to completely avoid local greenhouse gas emissions from fuel combustion. Therefore, a priority and urgent task is to replace old boilers that use gas or liquid fuel by the systems based on a heat pump. This replacement would not only reduce the consumption of fossil fuels, but also substantially reduce emissions of carbon dioxide.

Heat pumps are compact, economical and environmentally friendly heating facilities for hot water supply and heating houses that use low-grade heat source by transferring it to a heating agent with a higher temperature.

The benefit of heat pumps is their efficient performance: to transfer 1 kWh of thermal energy to heating system a plant needs to spend only 0.2-

0.35 kWh of electric power. Since the efficiency factor of conversion of thermal energy into electric power at large power stations is up to 50%, fuel efficiency when applying heat pumps rises. Another benefit of heat pump is the convenience of changeover from heating supply in winter to air-conditioning duty in summer, for that instead of radiator units fan coils or "cool ceiling" facilities are connected to an external collector.

The main heat exchanger element in the collecting system of low potential heat of the ground are coaxial vertical ground heat exchangers located outside the perimeter of the building. These heat exchangers are installed in wells with depth ranging from 32 to 35 m each, arranged around the building [2].

Nowadays there are many types of drilling rigs widely used in Kazakhstan. [3, 4].

Widely used nowadays mechanical auger drilling methods are more efficient in case of soft ground without solid rock and stone slabs. Drilling to the depth of 25 meters at well diameters up to half a meter with the above mentioned inconveniences can be difficult.

Electro-hydraulic drilling is a fundamentally new method that has not yet been applied in industry; the task of research and the practical use of this technology remains relevant to this day.

The unique benefits of this new technology are the following:

- opportunity to perform work in confined working space conditions (inside of constructed buildings, premises, basements, etc.) where it is almost impossible to use conventional drilling methods due to bulky equipment;
- long term reliable operation due to the absence of rubbing and wearing parts of the equipment;
- ease of operation and maintenance, that is achieved by the use as an active part a widely available cable electrode that is a consumable product.
- low power consumption and environmental friendliness of performed work.

This technology, as compared to conventional ones, makes it possible to demolish such obstacles as solid rocks more efficiently and in a short time when drilling wells for heat exchangers by impact of shock waves at high-voltage discharges in aqueous media.

2. EXPERIMENT

Electro-hydraulic effect is a high voltage electrical discharge in a liquid medium. During the formation of an electric discharge in a liquid energy release occurs within a relatively short period of time. A powerful high-voltage electric pulse with a steep leading front causes a variety of physical phenomena. Such as the emergence of ultra-high hydraulic pulse pressure, electromagnetic radiation in a wide range of frequencies up, under certain conditions, to x-rays, cavitations phenomena [5, 6].

To form the pulse with a short leading front voltage applied to the discharge gap in the liquid we used the discharge gap in a gas – a gas discharger, and in order to generate certain pulse energy an accumulating electrical capacitor was used. We developed and implemented into practice electro-hydraulic setup and working cell for drilling (Fig. 1).

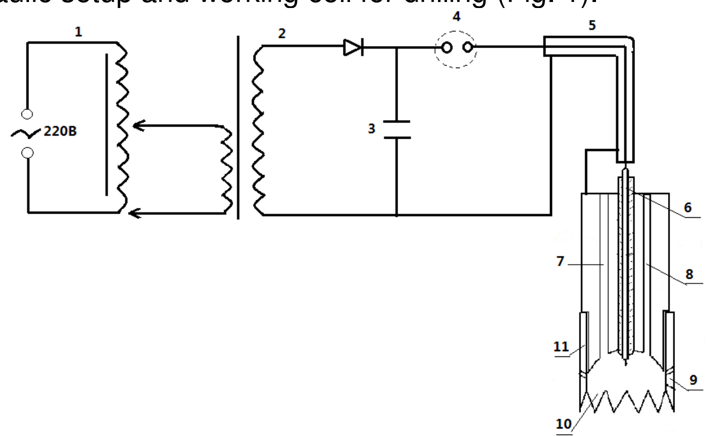

Fig.1. Scheme of electro-hydraulic apparatus and electro-hydraulic drill
1 – power supply, 2 – high-voltage generator, 3 – pulse capacitor, 4 – discharger, 5 – coaxial cable-electrode, 6 – centre electrode, 7 and 8 – water passages for injection the face, 9 – vent in the bit for gas outlet, 10 – teeth of the drilling bit, 11 – head of the drilling bit.

The setup consists of a power supply (1), high voltage generator (2), pulse capacitor (3) discharger (4), coaxial cable-electrode (5) and electro-hydraulic drill consisting of the centre electrode (6), (7) and (8) are water passages for injection the face, (9) – vent in the bit for gas outlet (10) – teeth of the drilling bit (11) – head of the drilling bit

The appearance of the electro-hydraulic drill is shown on the picture (Fig. 2)

Fig. 2. The appearance of the electr-hydraulic drill

The setup works as follows. Pulse capacitor (3) is charged by a high voltage generator (2), that powered by controlled power supply (1). When reaching the specified voltage a breakdown takes place in the discharger (4) and the energy stored in the capacitor through an electrode cable is transferred to the working part of the electro-hydraulic drill. A pulse electric discharge occurs in the fluid, the latter being a source of powerful mechanical shock waves that are reflected from the head of the drill and focused on a processed rock thus destroying it into small pieces.

As a result of the pilot study, the optimal values of time and the number of spark discharges at electro-hydraulic drilling stones are determined, the time for destruction of stones and solid rocks while drilling is defined.

The objects of electro-hydraulic processing were such solid rocks as natural stones. A natural stone is a material of quite diverse structure, often composed of various minerals that are often exposed to significant tensions in the formation process and the subsequent occurrence in the Earth's crust [7]. For the experiment natural stones of 5-6 hardness units by the Mohs scale were used.

Photos of processed natural stones samples are in the picture (Fig. 3).

1 2 3

Fig. 3. Photos of natural stone samples

As a result of intensive electric hydro-pulse processing of natural stones the mentioned samples were crushed into small pieces (see photo in Fig. 4).

Fig. 4. Photos of natural stones samples after electric hydro-pulse processing.

In the experiments, the electro-physical parameters of the setup were changed within the following limits:

$U_{\text{high voltage}} = 20 \div 35$ kV
$C_{\text{capacitor}} = 1$ uF
$l_{\text{razryad}} = 7 \div 12$ mm
$L_{\text{work}} = 25 \div 35$ mm.

Then the energy of the discharge at the working part changed.

$E = 250 \div 620$ J.

In experiments natural stones having an average thickness of 42 mm to 80 mm were processed.

Experiments were conducted as follows. On the surface of the stone located in a tank of water, an to electro-hydraulic drill was mounted. After feeding electric power to the set-up, the number of discharges for the destruction process was determined.

The resulting diagram of number of discharges dependency on the thickness of the stone at different values of energy is presented in Figure 5.

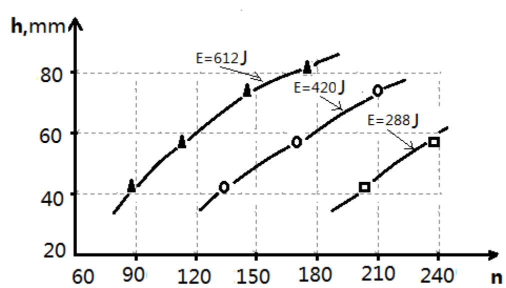

Fig. 5.The dependency diagram of the destruction process of stone of specified thickness on characteristics of electro-hydraulic pulses.

You can see that at the discharge energy level around 288 Joules destruction of a stone to the thickness of 55-60 mm is possible. The number of pulses is 230. When discharge energy rises, the thickness of destructed stones increases while the number of pulses required for destruction decreases. For example, at the discharge energy level around 612 J it is possible to destruct stones of 80 mm thickness. This requires less number of pulses of about 170.

3. CONCLUSION

On the basis of experimental research the limits of electro-physical parameters of method, when the intensive destruction of solid rocks – natural stones begins were determined.

The quantitative dependency, characterizing the beginning of the process of destruction of rocks of various thickness depending on the number and energy of discharges was defined.

The experimental work proved the possibility of achieving higher drilling speeds compared to those at conventionally used plants. The electric pulse destruction is implemented without using a drilling bit, it does not require special tightness of electrodes to bottomhole surface with considerable force; therefore, the wear of the electrodes at electrohydraulic pulse drilling is relatively minor.

4. REFERENCES

[1] Energy Strategy of the Republic of Kazakhstan for 2004-2015. – Astana.

[2] Vasiliev G.P. (1994) Use of low-grade heat of the ground of surface layers of the Earth for heat and cold supply in buildings. Heat and power engineering, (2), 31-35.

[3] Bondar E. S., Kalugin P.V. (2008) Heat pump as an energy efficient component of air conditioning systems. Electronic journal of energy service company “Ecosystems”,(5).

[4] Ray, D., McMichael, D. (1982) Heat pumps. Energoizdat, 224.

[5] Yutkin L.A. (1955) Electro-hydraulic effect. Mashgiz ,51.

[6] Yutkin L.A. (1986) Electro-hydraulic effect and its application in industry. L.: Mashinostroenie, 253.

[7] The Mohs Mineral Hardness Scale. By Andrew Alden (2010). – www.about.com: geology.

[8] Kusaiynov K., Sakipova S.E., Nusupbekov B.R., Turdybekov K.M., Kuzhuhanova J.A. (2012) Electric hydro-pulse development technology of heat exchangers production for using ground heat at shallow depths. Industrial Heat Engineering. - International Scientific and Applied Journal. Volume 34, (7),32-33.

Improved Four Photon Mixing Method for Optical Fibre's Parameters Control

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Abstract: *In our previous work we demonstrate the utility of a non-linear optical method, based on stimulated four-photon mixing to determinate the most important parameters of optical fibers. In this paper we propose improvement of this method which allows to control not only core diameter 2a, core-cladding refractive index difference Δn, normalized frequency V, and cutoff λ_c wavelength but also the concentration c of the core dopant. This in turn allows us to achieve greater accuracy in determination of the other fibers parameters.*

Keywords: *Fiber optics, non-linear optics, four photon mixing, optical communications.*

1. INTRODUCTION

At present most of the developed methods for control of optical fiber parameters determine only one of the fiber parameters [1]. In our previous work [2] we propose method based on nonlinear optical processes when measuring the frequencies shifts between new components and pump wave at stimulated four-wave mixing (FWM). As a result practically important fiber parameters such as: the core radius a_{cor}, the core cladding refractive index difference Δn, the cut-off wavelength λ_c, and the fiber V parameter are simultaneously determined. For practical application of this method we have to overcome two principal difficulties.

The first problem is related to the fact that the frequencies generated as a result of four-photon parametric mixing process are a function not only of fiber parameters but also of the real profile of refractive index. In [2] we were able to solve this problem.

The second problem is the following. The refractive index of the core in not known in advance. This problem for standard communication fibers might be easily bypassed taking into account the fact that these fibers have very weak dopant level of the core and consequently a small value of the core-cladding refractive index difference. Typical value is usually about $\Delta n \approx 10^{-3}$. Therefore approximation that the core is made of pure quartz is acceptable and does not lead to a large error. However, this approach is not suitable for fibers produced for special applications. In these cases the dopant concentration of the core can be very large and can reach values of approximately $c \approx 10-20\%$

In this paper we propose a method that might determinate the concentration of a fiber doped with a single element and on this basis determinate with high precision other fiber parameters. This method makes use of the Sellmeir formula in a fastly converging recurrent way that yields fiber parameters with high precision. We experimentally demonstrate this method for the case quartz fiber with a Ge doped core.

2. METHOD

As it is well known, the stimulated FWM is a non linear process, when two pump photons of frequency ν_p are transformed in Stokes and anti-Stokes pair of frequency ν_s and ν_a respectively, which obey the energy balance $\nu_p - \nu_s = \nu_a - \nu_p$. The process is efficient if the phase matching condition $\Delta k = k(\nu_s) + k(\nu_a) - 2k(\nu_p) = 0$ is fulfilled. Perfect phase-matching cannot be achieved in optical glasses because in the normal (anomalous) dispersion region Δk is always greater (less) than zero. Exact phase-matching is possible in optical fibers, when the material is compensated by the modal dispersion for a suitable combination of the modes, i.e.

(1) $\Delta\beta = \beta_{p1} + \beta_{p2} - \beta_a - \beta_s = 0$,

where β_{p1}, β_{p2}, β_a and β_s are the propagation constants of the waves in the respective waveguide modes.

The frequencies ν_a and ν_s generated by a FWM process can be accurately predicted, if the parameters of the fiber, including the refractive index profile, are precisely known. For a fixed modal combination, they can be calculated by varying frequency shift $\Delta\nu = \nu_p - \nu_s = \nu_a - \nu_p$, and looking for a $\Delta\nu$, at the phase-matching condition, expressed by eq.1.

For the case of weakly guided fibers [4] in a divided pump process (that is the Stokes and one of the pump wave propagate in one fiber mode, while the anti-Stokes and other pump wave propagate in another fiber mode) the frequency shift $\Delta\nu$ is determinate by Δn, V, $2a$, and n_{cor} as it follows [5,6]:

(2) $$\Delta\nu\lambda_p D(\lambda_p) = \Delta n\left[\frac{d(B_s V)}{dV} - \frac{d(B_{as} V)}{dV}\right],$$

where

(3) $$V = \frac{2\pi a}{\lambda_p}\sqrt{2n_{cor}\Delta n}$$

is the normalized frequency, λ_p is the pump wavelength, $D(\lambda) = \lambda^2\left(\frac{d^2 n}{d\lambda^2}\right)$ is the core material dispersion and $\frac{d(BV)}{dV}$ are differential mode delays of the propagating Stokes and anti-Stokes waves. These modal delays depend only on the V parameter and on the real profile of the refractive index of the waveguide core. They do not depend, however on any ever material parameters. For two distinct combinations of modes the following characteristic equation for the parameter V can be written [7].

(4) $$\frac{\Delta\nu^{(1)}}{\Delta\nu^{(2)}} = \frac{\dfrac{d(B_s^{(1)}V)}{dV} - \dfrac{d(B_{as}^{(1)}V)}{dV}}{\dfrac{d(B_s^{(2)}{}_s V)}{dV} - \dfrac{d(B_{as}^{(2)}V)}{dV}} = R(V).$$

In eq.4 indices 1 and 2 denote the first and the second modal combination respectively. As it has been shown in [2] If the refractive index profile is not known we can made appropriate choice of modal combination so the right side of the eq.4 to depend only on the V parameter. This fact established the possibility to obtain V parameter, and after that – the other fiber parameters.

When the parameter V is already defined, we can proceed to the determination of the other parameters of the fiber. Here is the second described problem. The core refractive index n_{cor}, dispersion $D(\lambda)$ and the differential mode delays $\frac{d(BV)}{dV}$, depend on the concentration of the core dopant element, which is not known in advance. For low doping concentrations we might use data for pure quartz [2], but at higher concentrations there will be an inevitable error when the fibers parameters are deduced.

In this case we propose a procedure that might overcome this shortcoming of the method. Usually the fibers are manufactured by cladding made of pure quartz and core made of pure quartz too but doped with some element in order to increase the refractive index. Typical dopant is germanium because the optical property of the GeO_2 are the same as the SiO_2 (quartz). In this case the method described makes use of iterative process that in one step makes a better fit to the doping concentration and the next one better fit to the Δn value. The procedure itself is the follows:

1. Via eq. (4) the V value for the pump wavelength used is found out.

2. At the first fit we select a zero value of the doping concentration $c^{(1)} = 0$ and for $n_{cor}^{(1)}$, $D(\lambda_p)^{(1)}$ and $\left\{\frac{d(BV)}{dV}\right\}^{(1)}$ we have the data for pure SiO_2.

3. Eq. (2) yields the first approximation for the core-cladding refractive index difference $\Delta n^{(1)}$.

4. Eq. (3) yields the first approximation for the core radius $a_{cor}^{(1)}$.

5. Next step we start with $n_{cor}^{(2)}$ defined as:

$n_{cor}^{(2)} = n_{cl} + \Delta n^{(1)}$,

where n_{cl} is refractive index for pure SiO_2.

6. This value we use to determine doping concentration $c^{(2)}$ relying on the modified Sellmeir formula [8] for two component mixtures:

$$n^2 - 1 = \sum_{i=1}^{3} \frac{[SA_i + c(GA_i - SA_i)]\lambda^2}{\lambda^2 + [SL_i + c(GL_i - SL_i)]},$$

where SA_i, SL_i and GA_i, GL_i are Sellmeir coefficients for SiO_2 and GeO_2 respectively.

7. With obtained value for $c^{(2)}$, using once again the Sellmeir formula, we can deduce the value of dispersion $D(\lambda)^{(2)}$

8. Next we can return to step 3 for the next iteration.

The iteration will end when step by step difference of the deduced parameters changes less than 0.1%.

3. EXPERIMENTAL RESULTS.

The effectiveness of this procedure was demonstrated for the case of the experimental results described elsewhere of FWM process in two types of quartz fibers with different levels of GeO_2 doping of the core [8], It is known from manufacturer's data, the fibers had pure silica cladding and Ge-doped cores with different molar concentration. They had been produced by the MCVD technique and a strong dip of the refractive index in the center of the core is present. The experimental set up, was widely used for studying non-linear phenomena in optical fibers. The fiber was pumped by the second harmonic of a Q-switched and mode-locked CW Nd:YAG laser. In the experiments the excitation of the different groups of modes was accomplished by varying the launching conditions for the pump beam. The modal structure of the generated radiation were identified visually, after splitting a fraction of the fiber output with a grating. FWM were recorded by OMA.

As an example In Fig.1 the anti-Stokes sides of the FMW spectra observed in one of fibers is shown. For this fiber the refractive index profile differ substantially from rectangular one. Fig.1 show also the modal combination of the Stokes and anti-Stokes components for the respective frequency. The Stokes sector of the spectra except the symmetrical Stokes frequency, contains also the stimulated Raman scattering (SRS) line with frequency shift 440 cm^{-1} from the pump. It complicates the spectra and increases the uncertainty of the adjacent FWM frequencies. For this sample we used $\Delta\nu^{(1)} = 722cm^{1}$ obtained with $LP_{21} - LP_{11}$ and $\Delta\nu^{(2)} = 1089cm^{-1}$ with $LP_{11} - LP_{01}$. Modes for second fiber are the same with respective frequency shifts $\Delta\nu^{(1)} = 384cm^{1}$ and $\Delta\nu^{(2)} = 929cm^{-1}$.

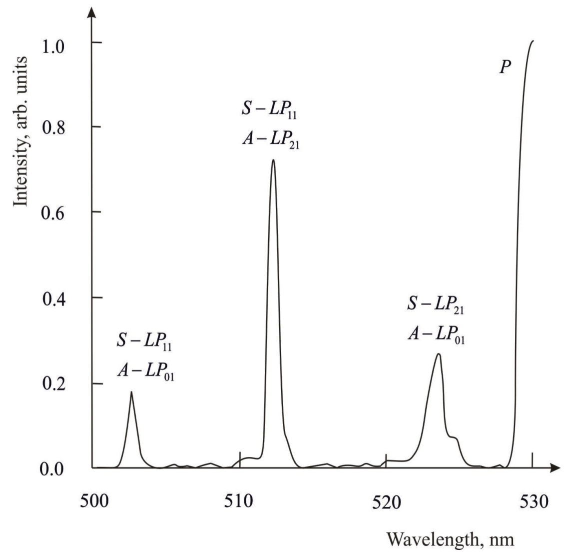

Fig.1 The anti-Stokes components of the FEM spectrum.

This measured quantities and Sellmeier coefficient for SiO_2 and GeO_2 glass taken from [8] has been used as starting parameters for our calculation. As an example results for Δn vs. number of iterations are present on Fig 2. It is clearly seen that no more than 4 to 5 iterations are necessary with our method to reach steady state value. Similar results are obtained for fiber diameter $2a$ and concentration c of GeO_2 dopant.

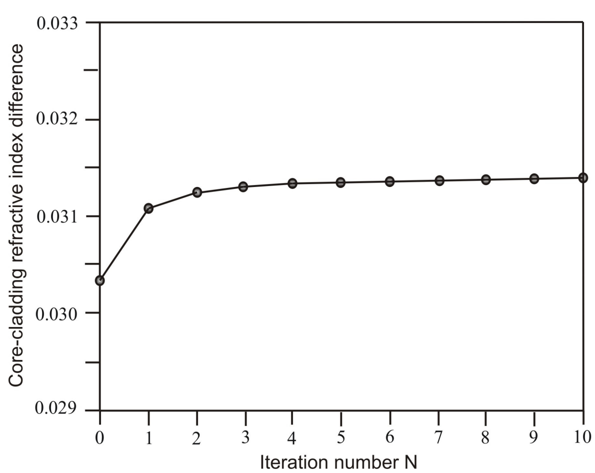

Fig.2. Core-cladding refractive index difference Δn vs. number of iterations

Table 1 is a comparison between our deduced values of fibers parameters with those supplied by the manufacturer. These data diverge no more 1%, that can be either an error inherent to the methodology used by the manufacturer or the method described herein. We perceive that that none of the methods used so far can serve as a fully reliable source for comparison.

Tab. 1: Comparison between manufacturers and calculations data.

Sample No.		Δn	a	$c(SiO_2)$
1.	Manufacturers data	$\approx 3{,}2.10^{-2}$	$\approx 2{,}2.$	≈ 22
	Calculations data	$3{,}18.10^{-2}$	$2{,}19$	20.6
2.	Manufacturers data	$\approx 2{,}3.10^{-2}$	$\approx 2{,}8$	≈ 16
	Calculations data	$2{,}42.10^{-2}$	$2{,}79$	$15{,}6$

4. CONCLUSION.

We demonstrate that the proposed method in this article is a reliable one for final quality control of fabricated fibre. All fibres parameters (Δn, $2a$, V, c) are determined at the same time. As a matter of fact we determine integral quantities that charactirize the whole length of the fibre via a FWM process.

This can be used with any type of dopant in a strictly two-component glass. However an uncertainty will arise whenever a multiple component glass system is to be considered.

5. REFERENCES.

[1] Agrawal, G., (2001) Nonlinear Fibre optics, London, Prentice-Hall International.

[2] Ivanov L.M, (2011) Non Linear Optical Effects in Quartz Fibers, Proceedings of the Fourth International Scientific Conference – FMNS2011, v.1, pp. 373-383, Blagoevgrad

[3] Stolen, R.H., Bjorkholm, J., (1982) Parametric amplification and frequency conversion in optical fibers, IEEE J. Quantum Electron., QE-18(7), 1062-1072.

[4] Gloge, D., (1971) Weakly Guided Fibers, Applied Optics, 10(10), 2252-2258.

[5] Stolen, R.H., (1975) Phase-matching-stimulated four-photon mixing in silica-fiber waveguide, IEEE J. Quantum Electron., QE-11(3), 100-103.

[6] Garth, S.J., Pask, C., Rosman, G.E., (1988) Stimulated four photon mixing in bent few-mode optical fibres, optical and Quantum Electronics, 20(1), 79-86.

[7] Stolen, R.H., (1975) Modes in fibre optical waveguides with ring index profiles, Applied Optics, 14(7), 1533-1537.

[8] Fleming, J. W., (1984) Dispersion in $GeO_2 - SiO_2$ glasses, Applied Optics, 23(24), 4486-4493.

Comparative study on carbon nitrid thin films obtained by CVD and PVD mecthods

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Abstract *Carbon nitride (CNx) thin films with an N/C ratio of 0.605:0.522 have been synthesized on Si(100) by: PECVD (plasma enhanced chemical vapor deposition) with different sources as a ksilol, CCl_4, N_2 and NH_3; HF (hot filament)-CVD (chemical vapor deposition) reactors; (physical vapor deposition) PVD method (electron beam evaporation of graphite and simultaneously nitrogen ion bombardment). The layers were analyzed by X-ray photoelectron spectra; Fourier transforms infrared spectroscopy and Raman spectroscopy.*

Key words: *carbon nitride, chemical vapor deposition, electron beam evapor*

1. INTRODUCTION

The existence of covalent carbon nitride, β-C_3N_4, with hardness characteristics similar to or better than diamond, was predicted in 1990 by Liu and Cohen [1]. Many studies have since been devoted to the synthesis of this material. Different groups have tried to prepare β-C_3N_4 on substrates like Si , W, etc. using a variety of systems as CVD and PVD methods: reactive (r.f.) sputtering in nitrogen, dc magnetron sputtering of graphite in an ambient of nitrogen, thermal or plasma decomposition of CH_4, C_2H_2 and N_2 or NH_3 , magnetron sputtering [2]; reactive magnetron sputtering [3]; ion beam and laser ablation processing; electron beam evaporation of carbon with nitrogen ion bombarderment [4, 5].

In all these approaches the β-C_3N_4 phase presents only as a small fraction of the entire layer, embedded in the amorphous carbon nitride matrix. Thin layers of β-C_3N_4 are also very prominent for microelectronics applications. I

In this paper we present a new results form of systematic charactization of the of C_xN_y layers in respect of methods and conditions of preparation. For synthesis of CN_x thin layers we are used: PECVD (plasma enhanced chemical vapor deposition) with different sources as a ksilol, CCl_4,

N_2 and NH_3; hot filament HF-CVD reactors; PVD method (electron beam evaporation of graphite and simultaneously nitrogen ion bombardment). For characterization of the layers Fourier-transform infrared (FTIR) spectroscopy, X-ray photoelectron spectroscopy (XPS) and Raman spectroscopy were used.

2. EXPERIMENTAL

In our experiments, we have used p-type (100) 40–60 V cm^{-1} Si wafers with diameters of 50 mm. The CN_x, layers were fabricated using one of the following CVD methods:

(1) From ksilol and N_2 in a PECVD reactor.

(2) From CCl_4 and NH_3 in an HF CVD at a temperature of the heating filament of 1200 °C and a distance between it and the silicon substrate of 5 mm.

(3) From CCl_4 and NH_3 in a PECVD reactor.

(4) By deposition of a carbon layer with a thickness of 6000Å on a silicon substrate and the subsequent treatment of this layer in a PECVD reactor in N_2 plasma.

The technological conditions of the processes in the two types of reactors are given in Table 1.

Table 1Conditions of samples preparation

Sample no.	Reagents				Type of reactor
	ksilol	CCl_4	NH_3		
1	20	-	-	120	PECVD
2	-	20	120	-	HV CVD
3	-	20	120	-	PECVD
4	SiC	-	-	120	PECVD

(5) In the PVD metchod CN_x thin films were deposited on the same silicon substrates by electron beam evaporation of carbon and simultaneous nitrogen ion bombardment. High purity 99.99% pyrolytic graphite and 99.9999% pure nitrogen were used as a target and sputtering gas. Electron beam with power 0.5-1 kW (at accelerating voltage 10-30 kV) and N^+ bombardment with low energies of 300-400 eV were used for deposition of the films. The substrate holder during the deposition was heated from 300 ^oC to 1000^oC.

FTIR, XPS and Raman spectroscopy methods were used for characterization of carbon nitride films.

3. RESULTS

Figure 1 shows the N 1s spectrum for sample 1, where approximately 75% of the nitrogen is in the form of N–O bonds [9], as calculated by the deconvolution. Figure 2 illustrates the N 1s spectrum of sample 2, obtained from CCl and NH_3. After a procedure of fitting, two peaks are obtained. The first one is broad, centered above 400 eV, and is typical for C=N and C≡N bonds with sp^2 hybridization. The second peak is also a broad one, but it is less intense, centered above 399 eV, and is characteristic for C≡N bonds with sp^3 hybridization.

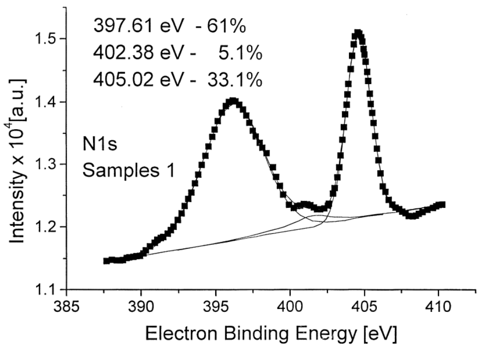

Figure1 XPS patterns of N1s peak sample 1(Table1).

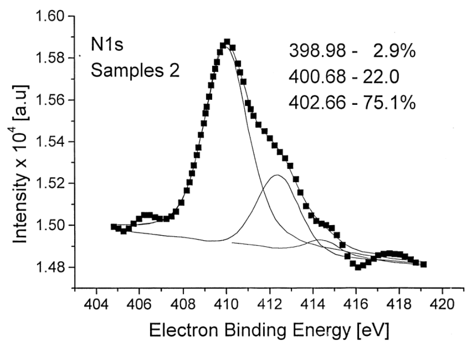

Figure2 XPS patterns of N1s peakfor-samples 2(Table1).

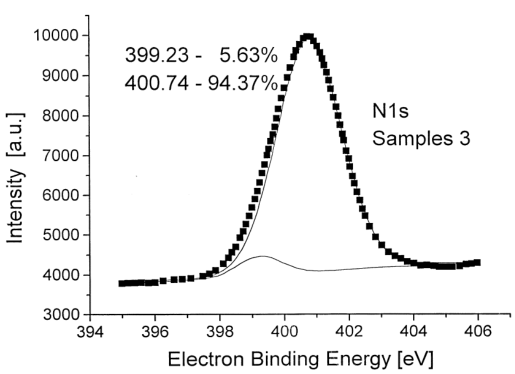

Figure3 XPS patterns of N1s peak sample 3(Table1).

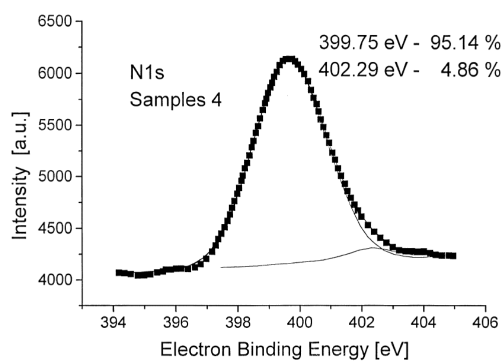

Figure4 XPS patterns of N1s peakfor-samples 4(Table1).

Figure 3 shows the N 1s, spectrum of sample 3, obtained after nitrogen plasma treatment of carbon layers deposited on silicon substrates. The spectrum consists of two peaks - the first is a broad one, it is situated at about 400 eV and is characteristic for C–N bonds with $sp^2$and sp^3 hybridization. The second is a low intensity peak at about 400 eV and is ypical of the N–0 bond.

Figure 4 shows the N 1s spectrum for the sample 4, which is comprised from three peaks. As can be seen from the figure, peak centered at 405 eV containing 33% of the nitrogen is due to complex ligands with NO bonds [9]. According to the peak centered at 399 eV about 90% of nitrogen is in C=N bonds with sp^3 coordination. The peak at about 400 eV is a characteristic of C-N bounds with sp^2 coordination. The low intensive peak in higher energy range is due to N-O bonds. Goodness of the fit is excellent but may be due to the higher BE value taken in accordance with recent work of Lopes [3] C-N bonding with sp^3 coordination prevails significantly.

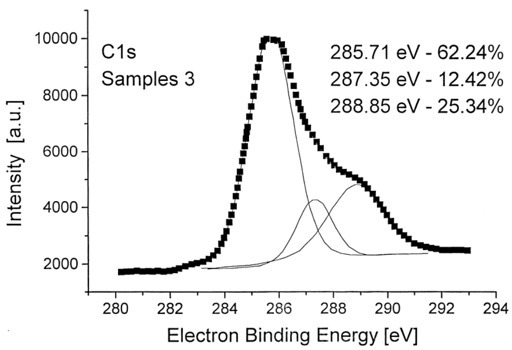

Figure5 XPS patterns of C1s peak for 3(Table1).

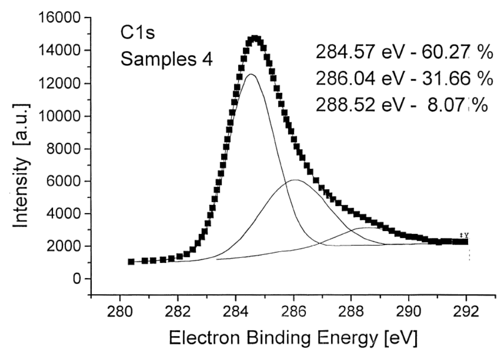

Figure6 XPS patterns of C1s peak-samples 4(Table1).

Figure 5 shows the C1s spectrum of the same sample (sample 3, Table1) and Figure 6 (sample4) after the fitting procedure. It can be see that the spectrum is split into three main peaks. The first is clearly visible with a maximum of 285.7 eV and is characteristic of the C–N bond with sp^2 hybridization. The second is broader with a lower intensity of 287 eV maximum and is haracteristic of CNN bonds with sp^3 hybridization. The third peak is situated at 289 eV and is characteristic for the C–O bond. Because of the presence of Cl 2p (from the CCl_4 source) in the broad spectrum , it can be assumed that there exists a complex compound of the type NCH3CONHCOCHCH [10]

Figure 7 shows the FT-IR absorption spectra (electron beam with power 1 kW, N^+ bombardment with low energies of 300-400 eV). Several absorption bands are observed in figure. Most of them are typical for carbon thin films and consist of peaks ranging from 900 to1600 cm^{-1}. The peaks at 1550 and 1150 cm^{-1} are usually assigned to graphite-like sp^2 carbon and disordered carbon with sp^2 bonds. With the increase of the substrate deposition temperature the IR spectra show an important additional small peak centered at 2150 cm^{-1}. This peak at 2150cm^{-1} is generally considered as representing C≡N bonds and ascribed to the presence of β-C_3N_4 phase in the matrix of the deposited films. Another peak at about 2325 cm^{-1} is characteristic to C≡C stretching mode [6, 7]. These results show that the incorporated nitrogen is chemically bonded to carbon with predominately sp^2 coordinated bounds and confirm the conclusion drawn from XPS and Raman spectra. However, the single bonded C-N phase is also presented in the deposited layers.

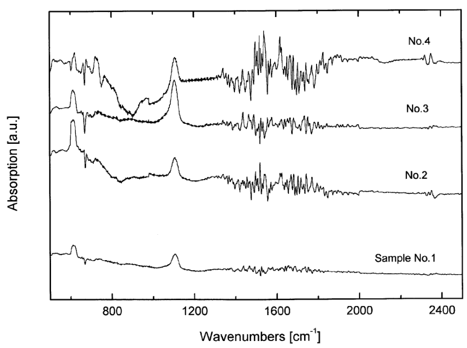

Figure 7 FTIR absorption spectra of carbon nitride films prepared at:№. 1 at 800°C; №.2 at 900°C; №. 3 at 950°C ,№. 4 at 1000°C.

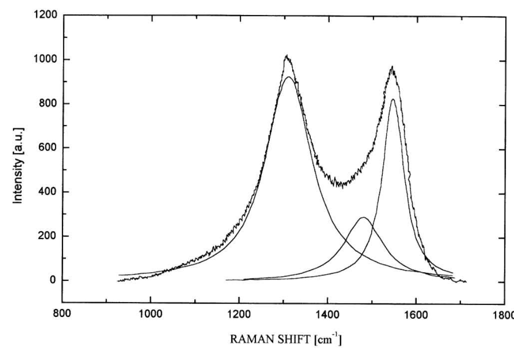

Figure 8 Raman spectra of samples at 1000°C.

Raman spectroscopy is widely used technique to identify the bonding and the microstructure of carbon and CN_x films [8]. Raman spectra of the sample 4 are shown in Figure 8. The Raman spectra are decomposed into three different Lorentian peaks. The two major peaks are observed at 1313 and 1548 cm^{-1}. These peaks are typical of diamond like carbon thin films. The peak at 1548 cm^{-1} is attributed to the presence of graphite phase (G). The peak at 1313 cm^{-1} is typically observed when the sp^2 disordered phase (D) is presented in the layers. The ratio between Raman intensity of the two Peaks I_D/I_G is about 2.4. This high ratio together with low intensities of the third peak at 1480 cm^{-1} may be attributed of C=N bond [8].

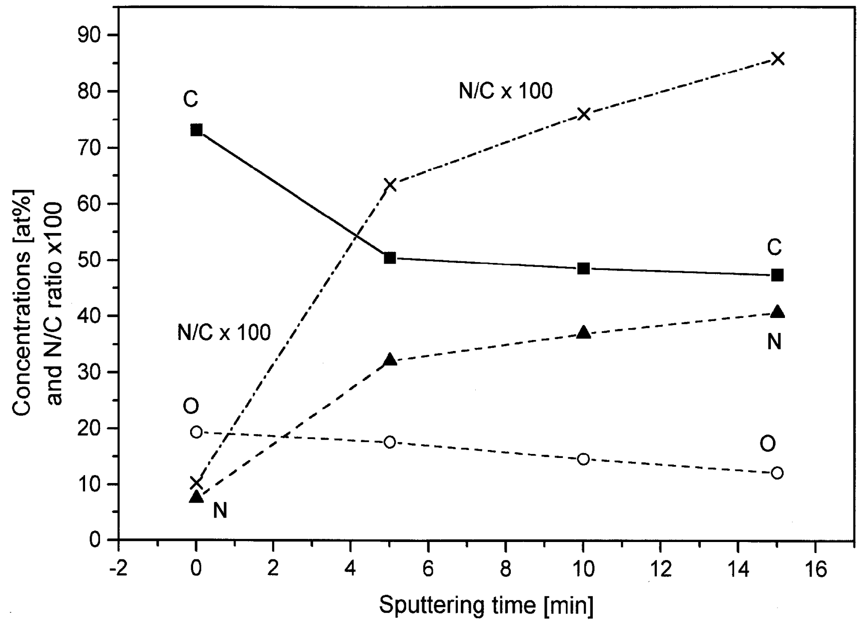

Figure 9. Carbon (C) and nitrogen (N) depth concentration profiles and N/C ratio.

Figure 9 shows depth concentration profiles and N/C ratio of 1 electron beam deposited at 800°C. As can be seen the amount of the nitrogen increases with sputtering time while carbon content decreases. Surface depletion of nitrogen is due to oxidation as a result of exposure of the sample to ambient atmosphere after the end of deposition process in vacuum.

Considering the behavior of C and N curves (Figure 9) a conclusion could be drawn that after 15 min Ar^+ sputtering the values of C and N concentration are characteristic of the bulk of the layer: the C/N ratio saturates. At this depth the layer consists of 47.3% carbon, 40.6% nitrogen and 12.1% oxygen. C/N ratio, which has the value 1.165, suggests prevailing of sp^2 coordination.

4. CONCLUSIONS

When the system Si–C is treated in nitrogen plasma, a considerable amount of C–C bonds are found, and when the source compound is ksilol and N_2, 33 % of the N_2 participates in complex ligands, which are probably due to the cyclical nature of the target compound. When the layers are obtained by HF CVD, it is difficult to overcome the incorporation of W in the layers, inasmuch that the W-heater is protected by a BN layer. We have demonstrated that a CN thin film may be synthesized on a Si substrate using electron beam evaporation of carbon and simultaneous nitrogen ion bombardment. In the synthesized layers, clusters of C_xN_y phase with $X > Y$ are included as it is proved by XPS and C/N ratio. Confirmed by FTIR and Raman investigations a second phase with coordination sp^3 exists consisting of β-C_3N_4 and diamond like carbon. These clusters probably are connected by carbon with sp^2 coordination. A negligible amount of C-O and N-O bonds is present.

The results of our comparative investigations of various methods and reagents for fabrication of C_xN_y layers with bonds having sp^2 and sp^3 hybridization clearly demonstrate that CCl_4+NH_3 proved to be the most suitable reagent for the PECVD deposition of CN layers.and the most effective method in respect of nitrogen incorporation is synthesis on a Si substrate using electron beam evaporation of carbon and simultaneous nitrogen ion bombardment.

5. REFERENCE

[1] A.J. Liu, M.V. Cohen, Phys. Rev. B 41 (1990) 10727.
[2] Sjostrom H, Ivanov I, Johansson M, Hultman L, Sundgren J,Hainsworth S, Page T, Wallenberg L. , Thin Solid Films, 246, (1994) 103.
[3] Lopez S, Dunlpo HM, Benmalek M, Tourillon G, Wong M,Sproul W. Surf Interf Anal 25 (1997) 315.
[4] Fujimoto F, Ogata K. Jpn J ApllPhys,32 (1993) L420.
[5] S. Veprek, J. Wiedmann, F. Glatz, J.Vac.Sci. Technol. A13 (6)(1995)2914.
[6] Ong CW, Tsang YC, Choy CL, Chan PW. Thin Solid Films,280 (1996)1.
[7] Kumar S, Tansley TL. Solid State Commun88 (1993) 803.
[8] Bhattacharyya S, Cardinaud C, Turban G. J ApplPhys , 83 (1988) 4491.
[9] Sharma J., Garrett W., Owens F., Vogel V.; J. Phys. Chem. 86, (1982)1657.
[10]Peeling J., Hruska F., McKinnon D., Chauhan M., McIntyre N.;Can. J. Chem. 56, (1978)2407.
[11] S. Bhatacharyya, C. Cardinaud, G. Turban, J. Appl. Phys. 83(1988) 4491.
[12] Gouzman I, Brener R, Hoffman A. Surface Science 331-333 (1995) 283.
[13] Ogata K, DinizChubaci JF, Fujomoto F. J ApplPhys76(1994) 3791.
[14] Mansour A, Ugolini D. Phys Rev B 47 (1993) 10201.

FPGA Development Board For Applications in Cosmic Rays Physics

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Abstract: *The modern experiments in cosmic rays and particle physics are usually performed with large number of detectors and signal processing have to be done by complex electronics. The analog signals from the detectors are converted to digital (by discriminators or fast ADC) and connected to different type of logic implemented in FPGA (Field Programmable Gate Arrays). A FPGA development board based on Xilinx XC3S50AN was designed, assembled and tested. The board will be used for developing a modern registering controller (to replace the existing now) for the muon telescope in the University and can be used for other experiments in cosmic rays physics when fast digital pulses have to be processed.*
Keywords: *FPGA, Spartan3A, muon telescope, cosmic rays variations*

1. INTRODUCTION

The muon telescopes are detector systems, which use coincidence circuits and counters, for continuous registering the cosmic rays muons intensity, in fixed angular intervals. The detectors are placed in two parallel planes, one above the other and when a charged particle passes a pair of detectors (of up and down plane) the corresponding coincidence circuit forms a pulse which goes to the input of the respective counter.

The muon telescope at the University consists of two detector planes, 9 detectors in each. 33 coincidence circuits and 33 8-bit counters are used [1]. The block diagram of the current registering controller is shown on Fig.1

The coincidence circuits are realized with fast AND TTL gates (74S08). The output of each coincidence circuit is connected to 8 bit counter (74HC590) and the 3-state outputs of the counters are connected to 8-bit bus. The one-minute time intervals for counting are formed by quartz stabilized timer. Additionally a 24-bit counter is implemented. The outputs of the 18 detectors are muxed sequentially each counting interval to its input, and the counted single pulses are used to control the proper operation of the corresponding detector.

The controller is connected to 2 parallel (LPT) ports of a personal computer – one of them is used as data bus and the other is used for sending commands and addresses.

Thus the designed in 2002 controller consists of about 70 TTL chips, (Fig. 2) and usage of LPT ports, unavailable on most of the modern computers main boards, imposes the need of new controller design.

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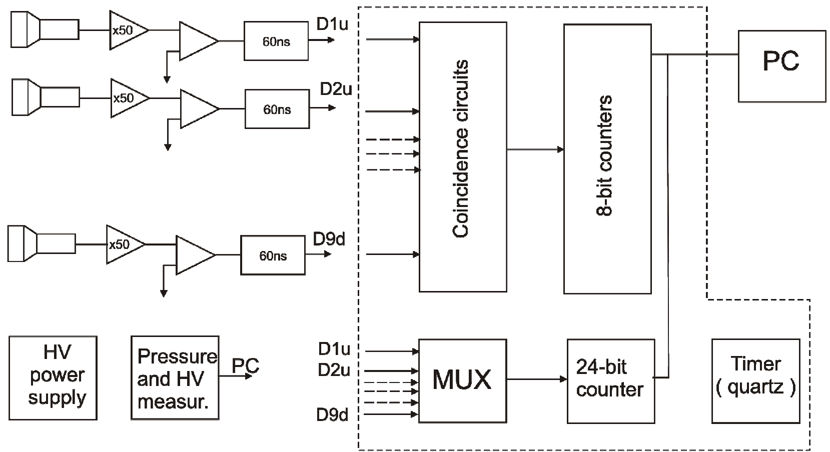

Fig. 1: Block diagram of the old TTL based controller.

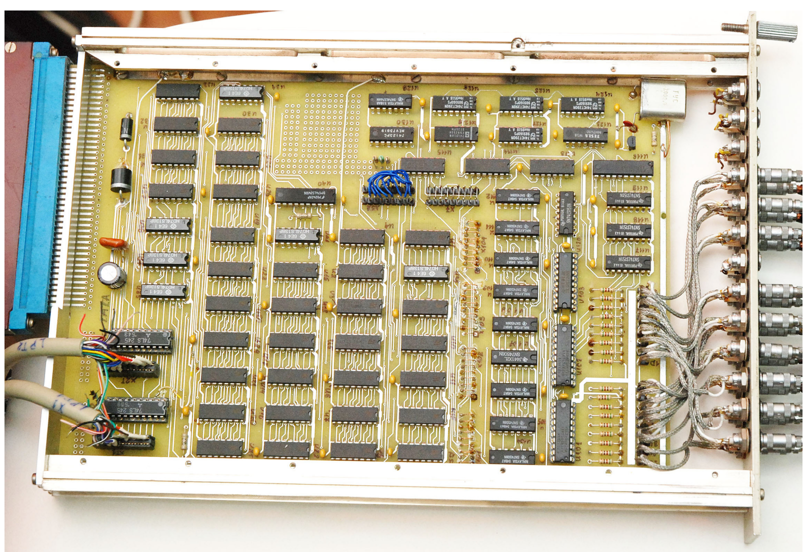

Fig. 2: Common view of the old TTL based controller.

2. THE DESIGNED BOARD

2.1 Main considerations.

The new controller has to be fully compatible to the other blocks of the telescope. It should have eighteen 5V tolerant 50 Ohm inputs for the 60 ns TTL pulses from the detectors and should realize the main functionalities of the old controller – 33 coincidence circuits and the corresponding counters from Fig. 1. The controller has to be designed using FPGA and VHDL, thus greatly reducing the number of chips and increasing the flexibility.

VHDL functional analogue of 74HC590 8-bit counters with outputs connected to common bus was preliminary tested on Digilent's BASYS-2 development board (Spartan 3E based) and for our design we chose Spartan 3AN family XC3S50AN chip. It has enough gates for this application, internal configuration memory and is available in TQFP-144 case, which allows hand soldering.

Before the realization of the controller, we designed the described in this paper development board, so the main blocks implemented in FPGA could be tested. Also some details of powering the FPGA, programming and board layout have to be clarified. The board was designed taking into account future possibilities for different VHDL codes tests and applications in other experiments.

2.2 The hardware.

The board is standard 2-layer PCB and was hand-soldered. The block diagram is presented on Fig.3., and common view can be seen on Fig. 4.

Its main characteristics are:

- Xilinx XC3S50AN FPGA, 50K gates, 144-pin TQFP case [2];
- 50 MHz quartz oscillator;
- 6 digit 7-segments LED indicators, dynamic indication;
- LED bar, 10 LEDS;
- 8 switches (High – Low level);
- 4 buttons;
- 20 inputs, 5V tolerant, 50 Ohm, 4 5V TTL inputs;
- 4 + 4 unbuffered 3.3V inputs/outputs (connected through 200 Ohm resistors directly to FPGA pins);
- Powered by USB;
- Two-channel UART-USB converter FT2232D [3] "on board";
- All signals of channel B of FT2232D wired to FPGA, possibility to use serial or parallel interface;

• Configuration without programming cable, directly by USB, using USB-JTAG interface realized with channel A of FT2232D;

• Configuration and programming by JTAG (USB-JTAG cable HS-1, Digilent);

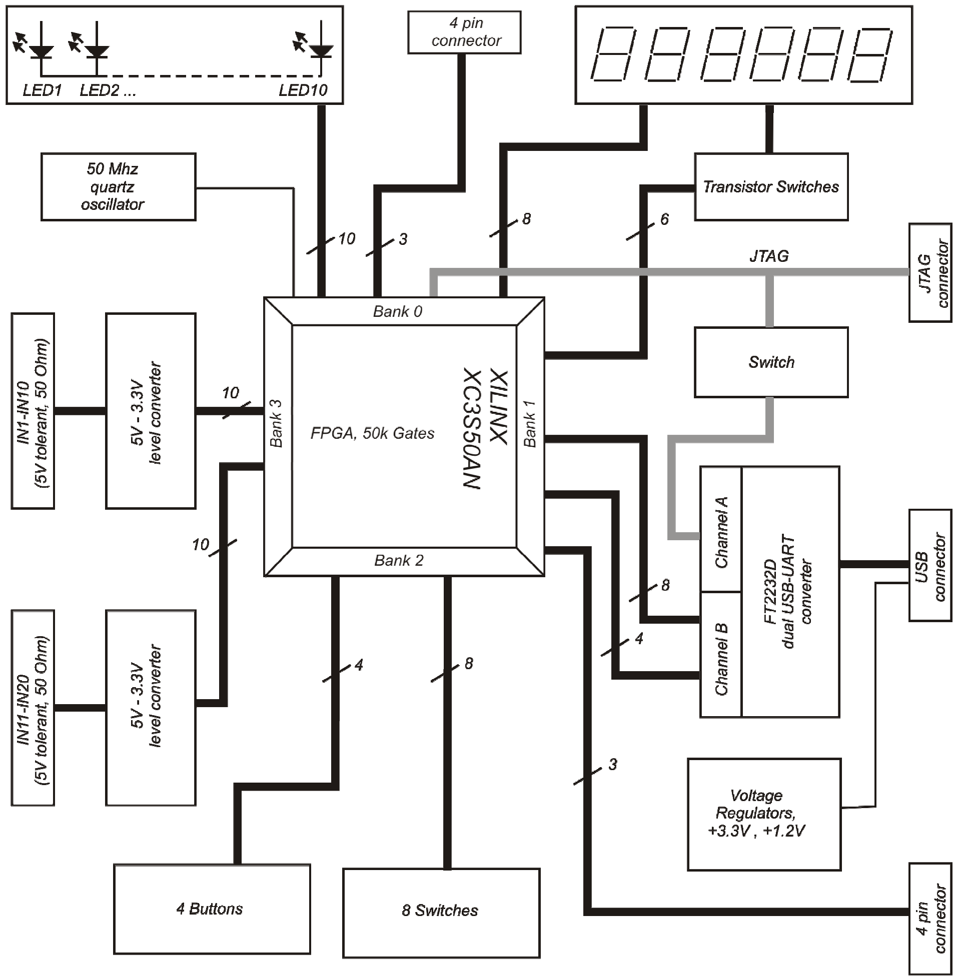

Fig. 3: Block diagram of the designed FPGA board.

2.3 Programming of the on-board FPGA.

The on-board XC3S50AN can be programmed by JTAG, using USB-JTAG cable HS-1, Digilent. It was tested successfully both with Digilent's software ADEPT and with Xilinx IMPACT (ISE 12.1), after installing the needed Windows drivers. The switch to channel A of FT2232D has to be “OFF”.

When the cable is disconnected, the on-board USB-JTAG interface with FT2232D can be used (the switch from channel A to JTAG should be “ON”) to configure the FPGA.

The open source PAPILIO-LOADER application (http://papilio.cc/, http://forum.gadgetfactory.net) was used successfully to configure the FPGA, loading bit-file into its configuration RAM. Although this software is capable of programming Spartan-3A FPGAs with external SPI configuration flash-memory, it can not program the internal flash of Spartan-3AN.

Several open source JTAG SVF-players were tested unsuccessfully to program XC3S50AN in this way.

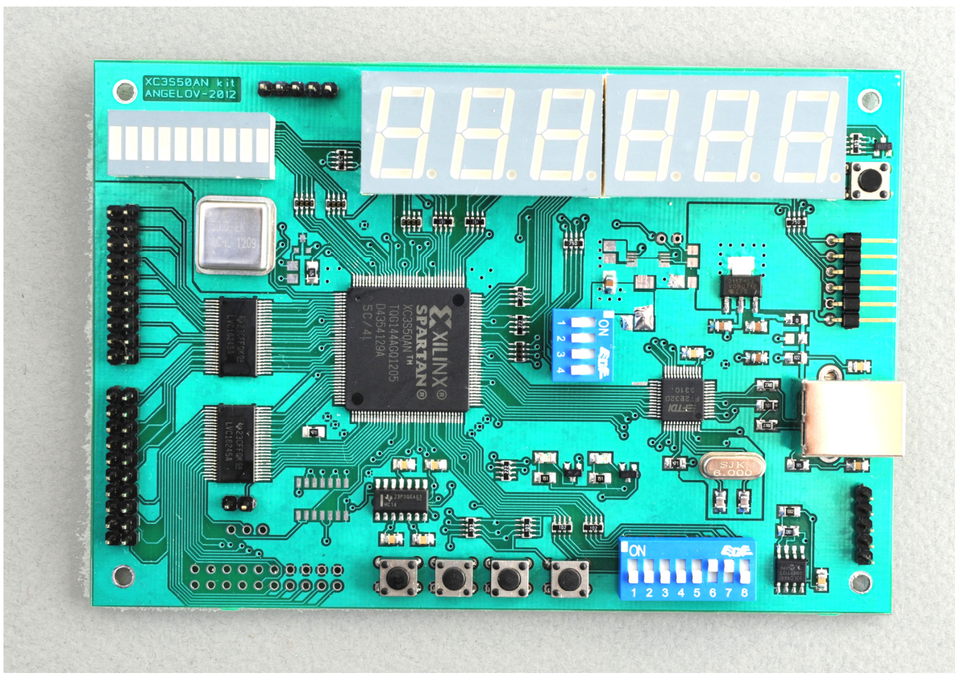

Fig. 4: Common view of the designed FPGA board. Actual size 129x88 mm. (Some SMD elements are on the bottom layer of the PCB)

3. CONCLUSIONS AND FUTURE WORK

A fully functional development board, with wide area of application, based on Xilinx XC3S50AN FPGA was designed and tested. Some details concerning powering, programming and other specific signals wiring for SPARTAN-3A and AN family devices were clarified. Previously designed blocks which were tested on BASYS-2 board (serial ports, counters and others) were tested on this board.

Detailed “Reference manual” consisting of table with user available pin definitions and including the full schematic diagram is available.

Currently the new registering controller schematic is at design stage using ISE Webpack 12.1. Before the final design of the new board, the project will be tested on this described dev-board.

4. ACKNOWLEDGEMENTS.

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5. REFERENCES

[1] Angelov I., Malamova E., Stamenov, J. (2008) Muon Telescopes at Basic Environmental Observatory Moussala and South-West University – Blagoevgrad. *Sun and Geosphere* **v.**3 – n.1 - 2008, pp. 32-37., available on-line: http://www.shao.az/SG/v3n1/SG_v3_No1_2008-p-20.pdf

[2] Xilinx (2011) Spartan-3 Generation FPGA User Guide , available on-line: http://www.xilinx.com/support/documentation/user_guides/ug331.pdf

[3] FTDI Chip (2010) Document No.: FT_000173 FT2232D DUAL USB TO SERIAL UART/FIFO IC Datasheet. , available on-line: http://www.ftdichip.com/Products/ICs/FT2232D.htm

Possibility for measurement of small changes of liquid's refractive index, related to the changes in liquid's concentrations

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***Abstract**: The goal of this current work is to show a possibility for measurement of very small shifts which is demonstrated with deviation of laser beam caused by its passing through medium with changing refractive index. Experimental setup for measurement of very small shifts of laser beam with CCD linear sensor is realized and verified experimentally.*

***Keywords:** measurement, refractive index, small shift of laser beam, CCD linear sensor.*

1. INTRODUCTION

There are different methods for refractive index measurement, described in [1].

The dependence of electric field $\boldsymbol{E}$ of a wave along the Oz axis on time $\boldsymbol{t}$ and distance $\boldsymbol{z}$ can be expressed by the equation:

(1) $E = E_0 \exp(i\omega t - kz)$,

where $\boldsymbol{\omega}$ is the angular frequency, $\boldsymbol{k}$ is the wave number and it depends of refractive index $\boldsymbol{n}$, $\boldsymbol{E_0}$ is the wave amplitude. This equation shows that $\boldsymbol{n}$ determines the wave phase and this is the basis of interferometric methods of refractometry.

Other methods are based on the reflection or transmission of light on interface between the sample and a material of known refractive index. The incident, reflected, and transmitted beams lie in the plane of incidence. In the first medium with refractive index $\boldsymbol{n_1}$, the angle of incidence and reflection made to the interface normal are equal; both $\boldsymbol{\alpha}$. The angle of transmission $\boldsymbol{\beta}$ into the second medium with refractive index $\boldsymbol{n_2}$ is given by Snell's law

(2) $n_1 \sin\alpha = n_2 \sin\beta$

If n_1 is known and the angles are measured, n_2 can be obtained.

Equation 2 is the basis of deviation refractometry.

Beneath is given a short description of refractive index measurement methods.

1. Interferometry

Sample with parallel input and output faces is placed in front of one of the beams of two-beam interferometer. From equation (1) a sample of length ***z*** and refractive index ***n*** causes a phase lag of $2\pi nz/\lambda_0$, compared with for the reference beam $2\pi n_{air}z/\lambda_0$ in air. The phase difference between the two beams is thus

$$\delta = \frac{2\pi(n-n_{air})}{\lambda_0} \quad (3)$$

The refractive index ***n*** is calculated after measurement of the phase difference ***δ***.

About 0.1 of a fringe can be judged by eye; electro-optic methods can measure 10^{-6} of a fringe. The method's potential precision is very high.

2. Deviation methods

Lateral and angular deviation methods make use of Snell's law (Equation 2). The incident beam is usually in air, of refractive index $\boldsymbol{n_{air}}$.

Lateral deviation ***l*** occurs for a beam of light transmitted through a parallel-sided sample of thickness ***L***. Equation (2) gives

$$\frac{n}{n_{air}} = \left[1+\left(\frac{\cos\theta_{air}}{\sin\theta_{air}-\frac{l}{L}}\right)^2\right]^{\frac{1}{2}} \sin\theta_{air} \quad (4)$$

The refractive index ***n*** is calculated by Equation (4) after measurement of the angle $\boldsymbol{\theta_{air}}$ and the distances ***l*** and ***L***.

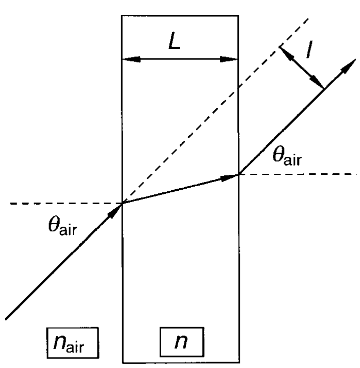

Fig. 2: Literal deviation

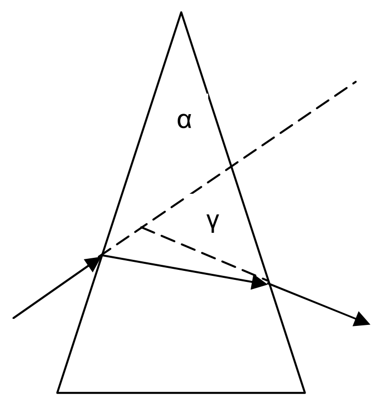

Fig. 3: Angular deviation

In the angular deviation method, parallel-collimated light is incident on one face of the sample of refractive index ***n*** in triangular prism form with vertex angle ***α***, the vertex line of the prism being normal to the plane of incidence. The refractive index ***n*** is calculated after measurement of the angles ***α*** and ***γ*** by Equation (5).

$$\frac{n}{n_{air}} = \frac{\sin\left(\frac{\alpha+\gamma}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)} \tag{5}$$

In addition, there exist several other refractive index measurement methods - including the critical angle method and Brewster angle method, which are also based on reflection and refraction of incident beam on boundary surface. These methods are relatively simple and have precision about 10^{-4} - 10^{-5}.

2. EXPERIMENT

The goal of this current work is to show a possibility for measurement of very small shifts which is demonstrated with deviation of laser beam caused by its passing through medium with changing refractive index.

The suggested experiment is presented on Fig. 4. Laser beam from light source 1 (He-Ne laser) falls under angle *α* toward the normal of the input window surface 2` of cuvette 2. After consequent refraction by passing through window 2`, analyzed liquid 3 and output window 2``, light comes out under angle *β* (equal to angle *α*) toward the normal of the output surface and reaches CCD linear sensor 4 connected to PC 5.

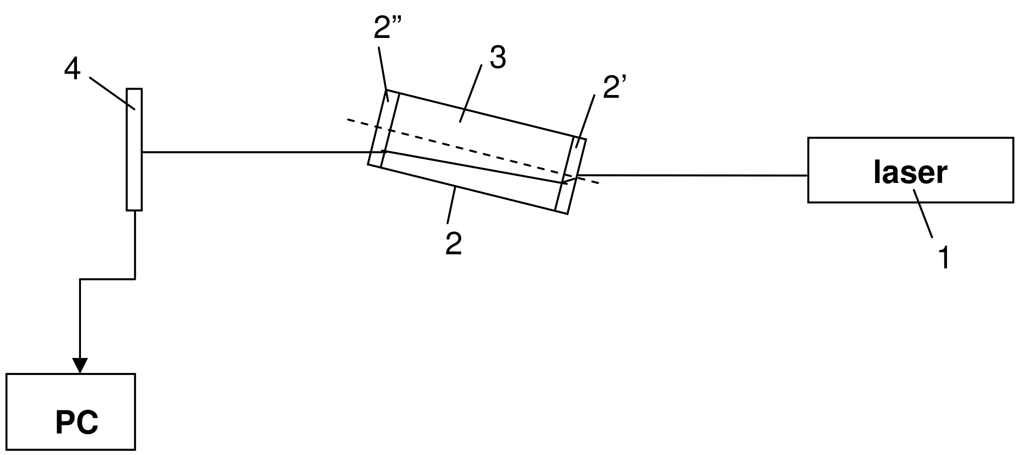

Fig. 4: The experimental setup.

Shifting of light intensity maximum of passing light from cuvette's axis depends on various factors, among which is also the refractive index of the liquid inside the cuvette. CCD linear sensor has 512 diodes, which are situated at distance 16 μm from each other, each of them is 12 μm wide. Consequently, there exists a possibility to measure shift of light's maximum of order of 28 μm. The measurements are made by fixed experimental parameters: incident angle $\boldsymbol{\alpha}$=15^{o}, window thickness ***a***=2 mm, cuvette length ***b***=96 mm, distance between output window and CCD linear sensor ***c***=85 mm). Fig. 5 shows the dependence of the shift as function of solution concentration by given parameters.

3. RESULTS

Measurements with sugar solutions with various concentration – 20%, 30%, 31%, 40% and 60%, are made. The shift of laser beam caused by its passing through a cuvette containing each of the solutions is measured toward the position of the laser beam passing through the same cuvette containing distilled water. The results of measurements of laser beam shifts as a function of solution concentration are graphically presented on Fig. 5 . On the same figure is shown also the shift obtained via computation. For the computation are used values of refractive index measured with Abbe refractometer [3].

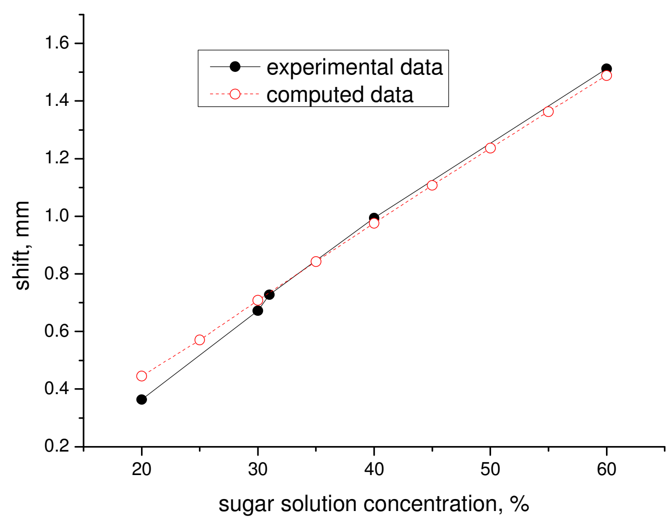

Fig. 5: The graph of experimental and calculated dependence of laser beam shift from sugar solution concentration.

Very good coincidence between experimental and calculated data is observed. The experimental graph slightly deviates from the straight line. This could be explained with the fact that sugar solutions, used in the experiment, are not absolutely accurate prepared. The solutions are prepared on the basis of dissolving of certain quantity sugar (measured in grams) in 100 ml solution, instead of dissolving it in 100 g solution (as it should be prepared). In order to eliminate the inaccuracy due to the difference between the given and the actual solution concentration it is necessary to measure the refractive index of the respective solution with Abbe refractometer and then to determine the solution concentration.

We will comment the result obtained by the measurement of two solutions with concentration difference of 1%. Theoretically calculated difference in the laser beam shift is 27μm. The actually measured difference is 56μm. However, as already mentioned the distance between two adjacent diodes is 28μm. So by the given experimental parameters we can measure minimal shift difference due to the concentration difference of 1%. This is corresponds to difference in refractive index in order of 0.002.

4. SUMMARY

Experimental setup for measurement of very small shifts with CCD linear sensor is realized. For validation are made measurements with sugar solutions. The experimental results confirm very well the calculated ones. Advantages of our experiment are good sensibility and direct data PC input. We can measure a difference of shift in order of 28μm.

5. REFERENCES

[1] Webster, John G., (1999) *The Measurement, Instrumentation and Sensors: Handbook*. Springer

[2] Nikolaeva, Z., Hristozov, D., Pavlov, R., (2007), A laboratory set-up determination of light's refraction coefficient, *Annual Assen Zlatarov University*, Bourgas, V. XXXVI(1), p.24-29

[3] (2004) Ordinance about the quality of the sugar used of person. *Official gazette,* Volume1.

Some peculiarities of teaching physics at the Natural Sciences and Mathematics High Schools in Bulgaria and Switzerland

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Abstract: *The present report makes a brief comparison between the fatual material in high school physics education in Bulgaria and Switzerland – two countries with fundamentally different public and economic development, mentality, culture and traditions. This affects the educational structure.*

Keywords: *education, educational system, physics.*

1. INTRODUCTION

The objective of the present report is to compare the educational systems in physics taught at Natural Sciences and Mathematics High Schools in Switzerland and Bulgaria and to reflect their positive and negative aspects. It will provide an opportunity to assess the possible activities on the basis of the already established traditions in order to achieve better educational quality.

Switzerland is a federal parliamentary republic consisting of 26 cantons, each one having its own government, parliament and constitution. This affects the educational structure as well – there are small variations across cantons. Switzerland is an orderly country in every respect, and its educational system is no exception. That is why the Swiss educational system is one of the best in the world. It is autonomous. The education in Bulgaria is organized and managed by the Ministry of Education, Science and Youth. It aims to meet the needs of young people to gain knowledge and qualification for better self-realization.

2. EDUCATIONAL SYSTEMS OF PHYSICS TRAINING IN BOTH COUNTRIES

The official language of the respective Swiss canton determines the language of instruction at schools. Primary education continues 4-6 years depending on the canton, secondary education – 7-9 years, being separated in two levels: the first one continues 3-5 years, and the second one - 4 years.

The elementary education system of the Republic of Bulgaria coveres the children aged 7-11, the primary education system – children aged 11-15 and the secondary education system – the children aged 15-19. Elementary and secondary education are compulsory. The children study physics in sixth grade. Natural Sciences and Mathematics High Schools in both countries have a long history, experience and traditions. They have been established for the graduates to gain secondary education with a focus on the natural sciences. Tab.1 shows characteristics of the educational process at Natural Sciences and Mathematics High Schools in Bulgaria and Switzerland.

Tab.1.Characteristics of physics education at Natural Sciences and Mathematics High Schools in Bulgaria and Switzerland

SWITZERLAND	BULGARIA
Educational purposes	
Pupils should be able to describe natural phenomena and processes briefly, clearly and consistently, to identify the physical interdependencies in everyday life, the relationships between natural sciences, environment and technics	Pupils should know the physical laws precisely and apply them in solving problems and explaining physical phenomena
Teaching methods	
They include both traditional and new, modern methods helping to obtain profound knowledge, to develop logical thinking in order to make real world sense	Problem solving and use of computer technology in teaching physics, traditional methods too
Guidelines	
To be familiar with the main discoveries in physics and the essential applications in technics and their interrelationship	To be familiar with the main discoveries in physics and the essential applications in technics and their interrelationship
To know and use the methods of physical knowledge (observation,description, experimentation, simulation, hypothesis, model, principles, theory)	To know and use the methods of physical knowledge (principles, theory)
To realize their simplest application in everyday life and technics	
Organization of the educational process	
Entrance examination	Examination in mathematics and physics at the secondary School after seventh grade
Duration of training 4 years	Duration of training 3 years

The educational profiles of Natural Sciences and Mathematics High School are „Biology and Chemistry" and „Physics and Application of Mathematics".	Profiled in Physics only at the National Natural Sciences and Mathematics High School - Sofia
Pupils decide for Profile „Physics and Application of Mathematics" or profile „Biology and Chemistry" Graduationpaper starts out in the second Semester of the third year and end in the first Semester of the fourth year	————————
Physics teaching is conducted separately as from the third grade according to the profile.	From the 10^{th} grade pupils are taught according to the same compulsory educational program
Free elective subjects	Free elective subjects
For their preparation pupils use notes worked out by the teacher in physics. He conforms with the compulsory themes and class profile.	The pupils learn from textbooks approved by Ministry of Education, Science and Youth. The teacher chooses this textbook of a publishing house that will be used by pupils
Teaching is in the form of a lecture	Pupils are actively involved in the learning process
Theory and practice are combined, and a clear idea of the application of physics in everyday life and technics is formed	Theoretical knowledge and solving problems prevail
Abundant material resources are shared by various schools in the region, as well as university resources	Insufficient and old material resources
Lessons include demonstrative experiments	Demonstrative experiments are rarely conducted, Poor material resources
Laboratory work is conducted with an experimental part, processing and reporting of results, conclusions. For this purpose, the class is divided into two subgroups	Conducting lab practicum is extremely difficult
The physics lab assistant maintains the equipment in good operating condition and assists the teacher in conducting laboratory exercises and experiments in the lessons to generate new knowledge	There are no appointed physics lab assistants at schools
Joint work between teachers and university lecturers is typical for the schools	Lack of feedback for common problems between school teachers and universities

Final assessment based on tests and laboratory work participation	Oral exams and tests. Regulation Nr. 3 of Ministry of Education, Science and Youth – pupils should have 3 marks per school term - one mark from a test and two marks from oral examination
The content of the maturity test is determined by the teacher of the relevant class. Criteria therefor are vocational profile of the class. With that maturity test everyone of the pupils is able to apply for university. If the pupil will entrance chosen of himself university, or not, depends on the recorded mark. The pupils do not need do an entrance examination in the university.	Physics is an elective subject, and matriculation exam is the unified state examination held on the same day for all schools in the country according to a syllabus previously set by Ministry of Education, Science and Youth. Matriculation exam consists of 50 test examination tasks With that maturity test everyone of the pupils is able to apply for university
Matriculation exam includes graduation paper	Matriculation exam does not include graduation paper

Natural Sciences and Mathematics High School Rämibühl conducts training course of four years duration aimed at obtaining Swiss Maturity Certificate. The distribution of lessons and curriculum is based on Bundesrat requirements of 16.01.1995 and on the regulations of Swiss Conference of Cantonal Ministers of Education (EDK) of 15.02.1995 on the recognition of school-leaving certificates, as well as of the curriculum framework of EDK and of education completion with Zürcher Maturität of 04.06.1996. The educational profiles of Natural Sciences and Mathematics High School Rämibühl are „Biology and Chemistry" and „Physics and Application of Mathematics".

Expected learning outcomes in physics – learners should be able to observe natural and technical processes and describe them briefly, present clearly mathematical formulation of physical interdependencies, build models and apply them to specific situations. They should learn how to use educational material and references, work with measuring equipment, conduct and analyze experiments and process their data.

Active work is carried out between high schools and universities. This is necessary because university lecturers are not aware of the educational level of the pupils, and school teachers have no idea of the entry requirements for the relevant university majors. Cooperation is crucial for mutual problem solving. University lecturers provide devices, educational material and multimedia.

Pupils graduate from high school after they have passed matriculation exam and defended a graduation paper. Exam themes and content of educational material covered by the matriculation exam are set by the teacher in physics of the relevant class. Criteria therefor are vocational profile of the class, pupils' abilities. During their final year at NSM High school learners of Physic and Mathematics profile have only two physic lessons (and an hour Practica), the pupils with main focus on Biology and Chemistry have also two physic lessons. This means, that the pupils with main profile Biology and Chemistry in the fourth class visit no more Physic lessons, but those with main focus on Physic and Mathematic have two-tree lessons per week for the academic year with the purpose of working together for developing projects and reports, preparing themselves for matriculation exam and university entrance exam. During the second semester of third grade pupils choose their graduation paper theme in a conversation with their teacher. It is not obligatory, that the Matura work must be in Mathematic or physical science.

Working on graduation paper starts at the beginning of the first semester of the fourth grade under the guidance of a high school teacher or a university instructor. Graduation paper for matriculation exam can be drawn up as an individual or a group project. Diploma provides admission to various universities.

Natural Sciences and Mathematics High Schools in Bulgaria were established over 35-40 years ago. Over the course of time they proved to be the schools where young people can obtain the best possible education in natural science and mathematical disciplines in the country. Many of their graduates have won awards in national and international contests, competitions and Olympiads, or continue their education at some of the most prestigious universities in the world.

Unfortunately the trend recently is to equalize the number of lessons, to confer Natural Sciences and Mathematics High Schools the same status as general education schools, and to close them gradually. This change will result in their liquidation, or they will be deprived of individuality. The courses profiled in physics have been almost liquidated. There is only one class profiled in Physics at the National Natural Sciences and Mathematics High School - Sofia, consisting of 29 pupils. In all Natural Sciences and Mathematics High Schools physics is not a profiled subject, and it is taught as in the general education schools - pupils have only 1 additional lesson weekly in 12^{th} grade as a compulsory selective training, in which they solve problems from Section Mechanics.

3. CONCLUSIONS

Although there are many differences between the state structures of Bulgaria and Switzerland and their educational systems, objectives and expected learning outcomes in physics of the secondary schools in both countries do not differ essentially. Themes covered by physics curricula almost overlap. They enable pupils to gain insight into most physical phenomena and to realize them, and make real and complete world sense for the adolescents. Some differences in the learning process can be pointed out:

- Material resources in Bulgarian schools are poor and insufficient to conduct demonstrative and laboratory experiments. This results in negative consequences such as low interest of learners in physics, their inability to work with physical devices and their superficial understanding of physical phenomena application in everyday life and technics. There is no active collaboration between teachers in physics from different schools, and between school teachers and university lecturers. Thus university educational requirements and secondary school training cannot be harmonized, and available material resources and literature cannot be shared. Total number of lessons in physics is extremely insufficient, and one should consider additional lessons in physics at least during the final year at high school.

- In Switzerland the final assessment in physics is based mainly on the results of test exams, and the new lesson is in the form of a lecture. It would be a good idea to focus on pupil-teacher discussion and oral examination. It will result in the easier assimilation of physical terminology and its use to describe and explain various phenomena and to develop logical thinking.

Some materials provided by Natural Sciences and Mathematics High School Rämibühl in Zurich and Natural Sciences and Mathematics High School Akad. Korolyov – town of Blagoevgrad, have been used in the article, and I am very grateful for their assistance.

4. REFERENCES

[1] HSGYM – Hochschule und Gymnasium, Hochschulreife und Studierfähigkeit, Zürcher Analysen und Empfehlungen zur Schnittstelle

[2] Lehrplan des MNG

[3] Наредба № 3 от 15.04.2005, ДВ, бр. 65/09.08.2005

[4] Учебни програми по физика, кн., „Учебни програми” - IIч,, (2000), МОН

The Scientific Essay as a Method of Teaching Physics and Astronomy in the Secondary School

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Abstract: *This article views the scientific essay in Physics and Astronomy as a method, which provokes the intellectual and creative abilities of the students for creating a short composition in a topic given. The article also points out which essay could be considered scientific, and how curiosity and creative thinking are applied for the writing of the essay. The preparation, writing of the composition and the evaluation criteria are described. There are also example topics for essays, connected with the compulsory education in Physics and Astronomy in secondary education.*
Keywords: *teaching Physics, scientific essay, curiosity, creative thinking, scientific interpretation.*

1. INTRODUCTION

In modern society, the priority in the educational policy is to ensure high - quality education. Education, concentrated on rousing interests in knowledge, is the main task of the teacher. He has to use different methods, to provoke the intellectual and creative abilities of the students so as to form cognitive interest in them. Such a method, commonly used in the pedagogical practice, is the scientific essay.

Recently, we have been witnesses of the disinterestedness of the youngsters towards natural sciences, including Physics and Astronomy. According to some authors, teachers in these subjects should apply approved educational methods to solve this problem. This will certainly regain the curiosity of the students towards nature, science and technics. Teachers' adjustment towards their role in class should also be changed. "Reality imposes more urgently to give significance to the fact that giving the maximum from yourself (including knowledge) and requiring something from others actually means to act in a forcible way. The question is: "How can we motivate learners in a favourable attitude towards learning?” [1]. The writing of a scientific essay is a creative approach which gives opportunities to answer this question.

2. CREATING A SCIENTIFIC ESSAY

An essay is a short written composition which includes personal thoughts and outlook in a particular problem. When the problem is in the field of science the essay is called scientific. It demonstrates the abilities to think in a critical and detached way, to interpret scientific facts and to argue personal point of view. In its work the student comments, confronts, seeks answers, makes inferences and conclusions. In this way the information turns into permanent knowledge.

The curious student may also make good logical reasoning in his or her composition. His thoughts are easily expressed when the he or she finds the subject interesting. It is known that one should be curious to find a topic interesting. Throughout curiosity we become well acquainted with life and the surrounding world, including nature and space. The eager - to - learn student is a motivated one, and he or she has interest in acquiring knowledge. These learners show interest towards science and their teacher knows how to promote this quality in his or her students. "The most important thing for a teacher is to know how to present the information and give examples where and when this information could be used - thus, why do they need to master it" [2].

Throughout his or her thinking, the learner applies the mastered knowledge in the scientific essay. Psychologists think that "only though thinking a person can pervade in the nature of objects, reveal the regularity in the development, and foresee the course of this development. Meanwhile, creative work is promoted through thinking, which is considered high level of knowledge" [3].

The composition is particularly appropriate when the creative abilities of the students must be evaluated. It is a well - known style in the literary set. The teacher should clarify the elements of the composition and the evaluation criteria. The writing should include introduction, main thesis and conclusion. The text should be well - structured and should show the logical attitude of the student. "The author's ability to advance arguments and express his or her thoughts should be shown. The text should be clear and accurate and should also specify the meaning of the scientific terms use" [4].

The writing of a scientific essay includes two stages. According to [4] they are:

- Preparation

In this stage, the writer analyses the thoughts and chooses the way they will be interpreted. He or she also clarifies the purpose of writing the composition and the information and ideas are arranged according to their significance. After that a suitable structural version is chosen and the text is divided into introduction, thesis, proof and conclusion(s).

- Writing

In the second stage, the student writes the essay, seeks and argues over the connection between facts and phenomena. The writer has to compare and oppose them, to give worldly, historical and scientific examples. Famous scholars, proverbs, sayings, etc. can also be quoted. Rhetorical questions are also used.

The Physics and Astronomy teacher has the hard task to evaluate the literary skills of composing a text on a scientific topic. Not all of the Physics teachers possess the philological preparation but these teachers can easily rate the scientific essay if they have the evaluation criteria in advance. The subjective point of view is at minimum if they pay attention to all the criteria, mentioned in the list.

In the pedagogical practice the following evaluation criteria can be used:

- Thesis

The thesis is rated according to its clarity, its appropriate wording, whether or not it expresses the personal point of view of the writer as a result of his or her own cognition.

- Well - grounded text

The motive has to possess logical value, clarity of concept and subject exactness. The text should be composed on factual materials. It is desirable that the text does not include only the personal opinion of the writer.

- Putting forward other points of view

Other arguments are discussed or the writer reasons his or her own points. The main literary, scientific and technical sources are rated.

- Language and style

The linguistic culture and the style of the exposition of the student as well as the correct use of scientific terminology are studied. When a particular term has different content in literature, the writer may also use other definitions.

- Structure

The essay must consist of introduction, thesis, proof and conclusion(s).

- Content

At least 9000 characters, or in other words, 5 standard typewritten pages [4].

3. THE CHANCE TO USE THE SCHIENTIFIC ESSAY IN THE COURSE IN PHYSICS AND ASTRONOMY

In the high school stage of secondary education, the Physics and Astronomy teacher may appoint essays as a way of an examination paper, homework or independent project. Table 1 includes example topics for scientific essays according to classes and chapters in the textbooks [5],[6].

Tab. 1: Example topics for scientific essays

Clas s	Chapter	Topic	Aims
9.	Electrostatic interaction	The meaning of the electrostatic phenomena for the human being, technics and nature	• To summarize the importance of electrostatic phenomena • To describe the influence of electrostatic phenomena on people and their daily routine • To make a comparison between electrostatic phenomena in nature and technics and to make conclusions
	Constant electric current	The electric current and the technical achievements of humanity	• To point out the importance of the electric current for technics • To describe the electrical appliances and to give reasons why they are so common • To make a connection between the technical mind,people's daily routine and the electric current
	Electromagnetic interaction	How magnets have changed people's lives?	• To describe the importance of magnets and electromagnets for humanity • To answer the question about their application in different appliances and equipment and how people use them in their everyday • To make parallel between electric current and magnets and to make conclusions according to their advantages
	Mechanical oscillation and waves	Are mechanical waves harmful or useful?	• To answer the question why mechanical waves are important to people and technics • To consider the tangible application of the mechanic

			waves • To compare the advantages and disadvantages of mechanic waves
	Electromagnetic oscillation and waves	The electromagnetic waves and their application in modern communication	• To make an analogy between mechanical and electromagnet waves and to point out the advantages of the electromagnetic waves • To describe the significance of electromagnetic waves for telecommunications • To point out the tangible communicational applications and to give reasons why they are so important for humanity
10.	Light	Stream of particles or a wave? - In other words - light!	• To summarize the light events and to point out their application in optics and life • To analyze the corpuscular-electromagnetic dualism for nature and light • To formulate conclusions on the base of quantum physics
	Physics of the micro world	Physics of 21st century	• To point out the global meaning of Physics of the micro • To argue the application of nuclear radiation in life, technics and power • To compare the fundamental interaction and to analyze their unification
11.	Astrophysics	Me and the night sky	• To make a survey of the heavenly bodies and their meaning for humanity • To point out and give proof of some of the contemporary methods for astronomical observation • To analyze the possibility for new astrophysical discoveries and future space missions
		The star is like a human being - it is born. It lives and it dies	• To describe the essence and the global meaning of the star evolution • To compare the stages of human life and star life • To summarize the conclu-

			sions for the evolution of the Universe from the star's point of view
		Is there any future for the Universe?	• To point out what is the content of the Universe, when and where did it originate and why is it important for the life on Earth • To present the scientific views for the present and to argue on the hypothesis for the future of the Universe • To prognosticate for the seeking of life and intelligence in the Universe and for the discovery of new universes and civilisations

4. CONCLUSION

The writing of the scientific essay is a complicated and responsible task. However, it is easily solved, when the student is curious, motivated and if he or she can easily express his or her thoughts in writing. The ability to use the freedom offered from this genre is a good opportunity for the creative presentation of the individual thought of the student. The pedagogical practice shows that the scientific essay as a method of teaching Physics and Astronomy is an effective method for interests towards science, technics, nature and space to be arisen. Bent though the mind and viewed from another angle, they are learned and rationalized well. This also develops the motivation for mastering of new knowledge.

5. REFERENCES

[1] Димова, В. (2011) Акценти в подготовката на физици. *Годишник на Софийски университет „Св. Климент Охридски"* 104, 46.

[2] Лечева, Г. (2009) Мотивацията – гаранция за позитивно отношение към учебния процес, *Научни трудове на Русенския университет* 48, 75.

[3] Тодорков, К. (2002) *Когнитивна психология*. В. Търново; „Фабер".

[4] Филипова, И., Тепавичаров, И. (2006) *101 идеи за иновативни учители*. В. Търново.

[5] Градинарова, М., Цеков, Х. и др. (2002) *Физика и астрономия, 9. клас, задължителна и профилирана подготовка*. София; „Анубис”.
[6] Градинарова, М., Райчева, А. и др. (2001) *Физика и астрономия, 10. клас, задължителна подготовка*. София; „Анубис”.

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