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QUANTUM GENERATORS, ENERGY AND PERPLEXITIES IN THE HISTORICAL DEVELOPMENT AND THE PRESENT STATE

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Abstract: In today's race for energy in general, classical and contemporary transformations, or more precisely, conversion of energy are considered in relation to more conventional and less conventional paths, transformations and transmissions and transport. The categories that are taken into consideration include: spontaneous/coherent, exotic transfer, commercial transfer and according to the area of some of the evaluations for efficiency coefficients, thresholds, defined in the concept of the system for obtaining energy or for the place of quantum generators with commercial application with one of the types of energy common nowadays. Quantum generator has also been discussed more widely with the aim of improving the experimental description or potential in mastering processes in the Cosmos as well as to contribute to the description of the depths of the earth in search of various resources, reflections, measurements and mainly quantitative descriptions of the world around our Globe including linear and non–linear phenomena.
Keywords: conversion/ transformation and transfer/ transport of energy; geothermal energy; lasers; measurement of produced energy; solar energy

1. INTRODUCTION

The demand for clean, dirt–free and simultaneously renewable energy has continued to increase around the world [1]. The great majority of these requirements furnished by wind and solar power as well as other alternative energy resources. Unfortunately, these resource types are discontinuous thereby requiring a good balance [1]. At this point, we are standing now at the historical crossroads with a huge assortment of worried human beings accompanied by a whole lot of physical and/or philosophical issues. As the plant and animal spheres have long been known and proven to predict cataclysms, earthquakes and to feel what is happening around them, so the industrial world and the mass media are in a state of enhanced awareness of the situation, as well as accelerated search for new energy sources, revision of old proposals and long term solutions for slowly evading this turbulent period. As we currently live in the fourth and approaching the threshold of the fifth industrial revolution in the present and future trends, a few selected issues related to both historical and recent publications of the mankind's successes, are presented with the same goal: analysis and search for some new answers to the global question of the optimization of energy consumption, the improvement of efficiency coefficients, approaching more suitable transformations of energy and near future forecasts, in the light of the philosophical approach, as well as the quality of energy transformation, along with incidental processes, which are the early types of recent hybrid and non–hybrid attempts. The places of quantum generators, in terms of energy, as well as in the most massive application of coherent processes/ phenomena, are sought [2–39].

2. A REMINDER OF THE PRESENT AND THE BEGINNINGS OF NON–CARBON ENERGY SOURCES. LASERS – GEOTHERMAL ENERGY

Successful tests with a high–power laser for crushing hard rocks in a geothermal drilling campaign have been carried out nowadays by a group of German and Swiss researchers from Laser Jet Drilling. The development of a method for laser drilling of hard rocks could be a revolution in drilling for geothermal energy, oil and natural gas. The Fraunhofer Institute for Production Technology IPT (Aachen, Germany) established an elite consortium to carry out those experimental stages. By drilling deep into the earth's crust, the temperature increases at a rate of $v \approx 0.03$ °C/m. In these types of jobs, drills encounter different layers of diverse materials and the drill bits wear out quickly. Eventually, this may lead to high costs, and thus prevent investors from actually implementing geothermal projects. However, the related activities performed by Fraunhofer IPT, together with partners, led to successful testing in field trials, and there were other activities (Foro Energy Company, which received funding for research under the ARPA–E program in the USA). There was a case when the researchers supplemented the mechanical drill with a high–power laser, the energy of which was directed at the rock using a jet of water, thus reducing the resistance of the material before the drilling process and the mechanical removal with the drilling tool was facilitated. The water jet prevented contamination and damage to the sensitive laser optics. To increase the speed of the drill and protect the cutting edges, additional energy was introduced into the well. By increasing the drilling depth, various materials and often unpredictable/unexpected were encountered, hence the laser was particularly suitable as a tool, due to its flexible performance settings.

The tests of the hybrid tool were also successful. A stand was set up in the machine and tool hall of the Fraunhofer–Institut für Produktionstechnologie IPT with a laser and a cutting tool (30 kW). In laboratory experiments, the project partners tested the process and made preparations for the transfer to real application. Hard stone, sandstone, granite and quartzite with parameters >150 MPa, were weakened by laser of up to 80%. In the next step, engineers used a laser on the platform in a special drilling column and successfully tested the new device in collaboration with International Geothermal Center Bochum for operation in real conditions. In future research projects, the partners wanted to improve the distribution of the laser energy and to add digital sensors to the hybrid tool, to provide feedback on the drilling process, in order to respond better to the changes along the wellbore.

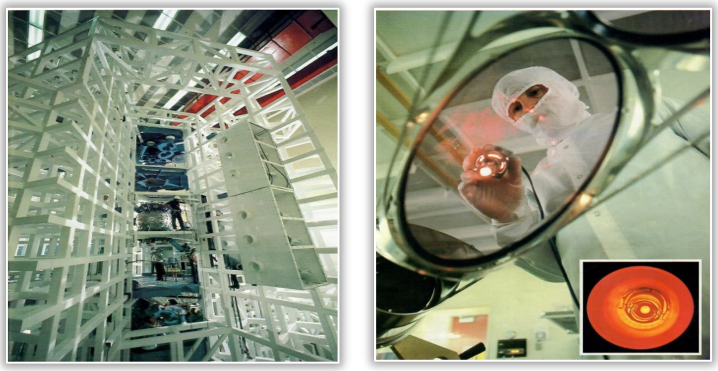
In contemporary energy trend, the issue of cost–effectiveness is always raised first for renewable energies sources. A powerful drilling system reduces the cost of deep geothermal wells and uses geothermal energy as an inexhaustible source of energy. This form of energy can take over a part of the basic energy consumption in the summation and supplement other renewable sources: sun, wind and water, compared to fossil fuels and nuclear energy. The institutions that performed research in this field were: GZB Inter. Geothermal Center Bochum e.V., Herrenknecht Vertical GmbH, Schwanau, IPG Laser Gm bH, Burbach KAMAT Pumpen GmbH & Co. KG, Vitten, Sinova S.A. (assoc. partner), Duillier, Switzerland Research project LaserJetDrilling funded by the Federal Ministry for Economic Affairs and Energy BMVi and supervised by Projektträger Jülich (grant no: 0325784A) [1, 2].

3. SKETCHES OF HISTORY AND THE PRESENT: LASER FUSION, HYBRIDS, TOKAMAK, GYRATRONS – RED BEAUTIFUL PHOTONS

Among the grey–brown hills 56 km southeast of San Francisco was a vision for the 21st century. In a gloomy rectangular building, a complex white gleaming steel grid structure held the world's most powerful laser of its time. In there, 20 beams were directed into an enclosed metal structure /a chamber that resembled a levitating UFO (or pile of scrap iron after the last frame of a Star Wars movie). This was the Shiva laser of the Lawrence Livermore National Laboratory of the University of California, where hydrogen (H) *particles* in the chamber were *bombarded* with laser beams. That would be the scientific proof of fusion. Earlier activation of thermonuclear fuel, and the many–armed Shiva (Indian deity) was created to make H particles like grains of salt, glowing like miniature suns in billionths. It was supposed to be the scientific breakthrough over the last 4 years, when one of those artificial suns would produce the amount of energy needed for the operation of the laser system. The $25×10^{6} project required 100 companies for their work, knowledge and skills. The test yielded more than the strength predicted. Bombing with Shiva is like launching a rocket with a countdown of 5 min. before the ignition. The switch in the control center was turned on, followed by a sequence of actions controlled by the computer to check the safety. A large capacitor, a short–lived accumulator battery, was charged from the mains. Turning on the main switch activated two thousand flash lamps in the pumping process. After ≈ms, their laser pulse would propagate through the system.

The mirrors formed 20 beams towards the chamber, conically focused. For less than ns, the fuel particles were hit with a power 25× higher than all the electricity power in the US. Compression generated a material of density 100x greater than that of Pb, and caused the implosion of the H– balls and the activation of fast neutrons to produce electricity, Figure 1 one of the technologies that is meant to unlock almost limitless ultra–deep geothermal energy. Variants of these photographs have been published in publications on different languages.

Quaise – a stem company–off of MIT – was supposed to use the "hijacked" fusion technology to drill the deepest holes in history, providing clean, virtually unlimited, supercritical geothermal energy that can re–power fossil fuel power plants around the world. The Earth's core is hot, but there are surprises, too. It was estimated that the temperature to be in the iron core ≈5200°C, generated by the decay of radioactive elements combined with pressure, from the very formation of the planet – a cataclysmic event, when a swirling cloud of gas and dust was compressed into a ball. The deepest hole that humanity has managed to drill is the super–deep Kola borehole [10]. A Russian project near the Norwegian border (1970) aimed to penetrate the crust all the way to the mantle, and one of the wells have reached a vertical depth of 12289 m in 1989, before the Kola team ran out of funds and decided it was impractical to go any deeper. The expected temperature was ≈100 °C, but in reality it was ≈180 °C. The rock was less dense and more porous than expected, and these factors combined with the elevated heat created the conditions for drilling. The Kola site has been abandoned. Rakot13 (CC BY–SA 3.0) was one as the world's deepest drilling project. Germany has invested more than $\$2.5\times10^9$ on its own version of *deep–hole* in the late 1980s, but the Continental Deep Drilling, or CDD, program only got as far as 9101m before shutting down. The temperature rose much faster, and the CDD team was surprised that the rock at this depth was not solid and that large amounts of liquid and gas poured into the well and further complicated the work. Temperatures were high enough to prevent further drilling. It has also provided a good output of geothermal energy. Although these and other projects have provided invaluable scientific results and resources, new technologies are still needed to discover and exploit further, the geothermal potential. For direct energy drilling, when conditions become too difficult for physical drills, researchers have tested the ability of directed energy beams to heat, melt, fracture or vaporize rock in the blasting process, before the drill head even touches it, Figure 2.



(a) (b)

Figure 1. Fusion – Steel construction for once the most powerful laser in the world at the University of California. The laser beam is directed at the H atoms in the chamber, for fusion reactions, which may give more certain (less than "final") answer for the solution of the energy crisis; from: Bylinsky, G.: Shiva: the next step to fusion power, Fortune Jan. 30, 1978 and from: doi.org/10.2184/lsj.5.318 (a); compound photo by John G. Zimmerman, Fortune, Jan. 30, 1978 (source: John G. Zimmerman archive – PhotoShelter) (b).

Figure 2. Petra's"Swifty" robot heats and grinds the hardest stone on Earth, without touching it [14, 15].

Military experiments in the late 1990s have shown that drilling based on laser techniques is 10–100 times faster than conventional one. It was of great interest for oil and gas companies. The direct energy drilling process, K. Oglesby, offered tremendous advantages: 1) no mechanical systems in the borehole to wear or fail, 2) no temperature limitations, 3) easy penetration of rocks of any hardness and 4) a potential to replace the need for casing/cementing with a durable vitrified lining. The last one is interesting – a direct energy drill would effectively burn the rock in bore hole, dissolving it, and vitrification occurs into a glassy layer that seals in liquids, gases and other contaminants, which has not been addressed before. It had been stated: "The deepest penetration into rock achieved so far by lasers was only 30 cm." There are fundamental physical and technological reasons for this lack of progress in laser drilling:

— the flux of particles extracted from rock is not compatible with the short wavelength photon beam, it is scattered and absorbed (by dust and particle clouds) before coming into contact with the desired surface rocks;

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— laser technology does not have enough energy, efficiency is low and the process is too expensive. It should be directed on plasma heating and fusion research and DOE funding have progressed through the gyrotron.

With gyrotron and mm–wave energy beams, the solution may come from the world of nuclear /laser fusion. To replicate the conditions that break apart atoms in the Sun's core and release the safest and cleanest form of nuclear energy, fusion researches must generate large amounts of heat. It is in the range of 150×10^6 ^oC, the ITER Project, $\$10^9$ from international government funding have been committed to fusion research. Progress and commercialization have accelerated in other areas without a formal budget as well. The gyrotron, as a component of equipment, was originally developed in the USSR in the mid1960s. We remind that gyrotrons generate EM waves in the mm–part of the spectrum. In the early 1970s, research into the design of Tokamak for the purpose of fusion reactors led to the conclusion that mm–waves were excellent way to significantly heat plasma. In the last 1950s, gyrotron development has made a significant progress, along with fusion research, and DOE funding, Figure 3. Gyrotrons are available when they generate CW energy beams of power >MW, which were amazing news for deep–planet drillers. The scientific basis, technical feasibility and economic potential of rock drilling with directional wave energy (in the range 30–300 GHz) are strong. It avoids Rayleigh scattering and can deliver energy to rock surface more efficiently (>90%) guided over long distances (>10 km) in various modes and waveguide/tube systems, including the potential of wound and smooth–bore coupled ones. "Thermodynamic calculations" suggest penetration rate of 70 m/h, which is possible in 5 cm boreholes with a gyrotron (1 MW) which interacts with the rock at ≈100% efficiency. Lower or higher power sources (100 kW – 2 MW) would allow for changes in bore hole size and/or penetration rate. That would be a big boost to traditional oil/gas drilling projects – but without further surprises, the equation for ultra–deep drilling and the *profitability* should be significantly changed in order to allow getting deep enough into the crust and release some of the Earth's vast geothermal energy potential.

Figure 3. A 1–MW, 150–GHz gyrotron used to heat plasma in the Wendelstein 7–X stellarator fusion experiment in Germany [15, 16] (CC BY–SA 4.0).

In 2018, MIT's Plasma Science and Fusion Center developed Quaise, targeting ultra–deep geothermal energy using hybrid solutions: a combination of g–rotary drilling with mm–wave/ gyrotron technology, while pumping Ar–gas to purge and cool the well while spending ≈ $\$81\times10^6$ in initial funding, and through planning $\$45\times10^6$ (grant funding in the series). A hole was closed earlier than expected. While the Kola team needed ≈20 years to reach the limit, the PSF Centeris expected to plan holes up to 20 km deep with the gyrotron–Quaise, significantly deeper than the Kola Super deep improved processes, in 100 days. Quaise's hybrid ultra–deep drilling rig was to combine conventional rotary 500°C, well beyond the point where geothermal energy reaches "a big jump" in the efficiency. Water was a supercritical fluid. It was expected to be drilling with mm–wave gyrotron directed energy processes (Ar gas) with systems parameters 22 MPa and 374 °C.

A power plant using supercritical water as the working fluid is up to 10× more efficient when compared to non–supercritical ones. Those conditions are the key for achieving higher power density and relationship with fossil fuels. Further work is underway on demonstration devices to be installed in the field, until 2024. It was planned that the first "super–hot enhanced geothermal system" of 100 MW is to be in operation in 2026. It would then exploit the existing infrastructure (made for fossil fuel/coal power plants), which will eventually be closed as CO_2 emission limits become more stringent. These facilities already have large steam–to–electricity capacities, established commercial distributors and a link to the electric grid. Replacing current fossil fuel heat sources with enough supercritical geothermal energy will become feasible (planned for 2028). The aim of these plans is that the heat becomes available to the everywhere on Earth. It is estimated that > 8,500 coal fired power plants exist in the world, with a total capacity of > 2,000 GW, and all of them will have to transform their way of operation by 2050. A large amount of carbon–free energy is needed for the next decades and centuries!? The future of clean energy

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sources is connected to these efforts. Social networks (Facebook, twitter, flipboard, Linkedin) have long been conducting polemics of type: a) How a few geothermal power plants can solve America's Li–source? b) are claims that Earth should be abandoned for another planet believable? c) Why fusion will not save us from decarbonization?

An introduction to the Triassic: current insights into the regional setting and energy resource potential of NW Europe are around–collecting people. The company "Quaise Energy" offers one of the most resource–efficient and scalable solutions for powering our planet. It complements current renewable energy solutions and enables sustainable base load energy to be achieved in the not–too–distant future. It seems that is forward for basic clean energy and the decarbonization process. If this technology works as expected (and the crust doesn't find new ways to fight back our incursions); the new use of gyrotrons could make fusion reactors unnecessary!? Importantly, they will take up almost no space on the surface, unlike the sun and wind. This, it is thought, will also accelerate global geopolitical change. Every country will have the same access to its own practically inexhaustible source of energy, and it will certainly be nice that large countries do not have to "liberate" the population of smaller ones in order to gain access to energy sources. Quaise, connected for the future of clean energy sources is tied to these efforts. Prelude Ventures were some of the key investors of the series.

4. LASERS AND SPACE INVESTIGATION AND OUTPUTS FOR ANTICIPATED 700?!

There are also opinions that before the wells are opened, the consequences should be predicted, and people are only concerned about their apartments and optimal living conditions. The gravitational point of view of the Cosmos/Space of the solar system was also discussed and modeled. Solar powered aircrafts, Figure 4a, 4b, as well as laser sailing, Figure 4 c, could be a "game changer for exploration."

(a) (b) (c)

Figure 4. a) An artist's impression of the Airbus UAV Zephyr [19] (source: Airbus Defence and Space); b) Zephyr, pictured during a 2021 test flight launch [20] (source: Airbus); c) Theory, possible and real effects and Space [21, 22] (source: pubs.acs.org/doi/10.1021/acs.nanolett.1c04188).

It is reported that unmanned aircraft vehicle (UAV) Airbus "Zephyr S" took off from the U.S. Army's Yuma Proving Ground on June 15, 2022 and has since been flying patterns over the Yuma Test Range and Kofa Wild life Refuge. The UAV has been in the air above the Sonora Desert for 42 days, breaking its own record for longest unmanned flight. The flight "has now broken Zephyr's previous record of 25 days, 23 h that it set in Aug. 2018 [19, 20]. Being solar–powered and not requiring fuel or oxygen, Zephyr could operate at altitudes from 20 to 100 km for months and could be beneficial for telecommunications, video/imagery, radar for flight control, weather radar, etc.

Fusion research is always 20 years from success. A small spacecraft with laser–powered sails could develop higher speeds and potentially traverse much greater destinations than conventional rockets. Current spacecraft with rocket fuel travel the solar system for thousands of years. NASA's New Horizons reached Pluto in 2016. Alpha Centauri, the closest system to earth is 4.37 light years away—more than 41.2 trillion km. NASA's Voyager 1, launched in 1977, arrived in interstellar space in 2012 and it will take about 75,000 years away to reach Alpha Centauri. The problem with all rocket thrusters is the mass they carry, especially for long distances. A low–power laser (red cone), would move a small probe (grey circle) away from the earth, through the orbits (red shift), or propel it at high speed to Neptune and beyond.

Going interstellar within a reasonable time frame imposes more constraints than potential challenges within the solar system. Research has shown that "light sailing" can be one of the solutions for reaching another star during the current limit of human life. Although light does not exert a high pressure, in space, even a small pressure can have a great effect. Experiments have shown that "solar sails" can rely on sunlight for propulsion, if a spacecraft has small mass and a large sail. That's why the discussion shifted to laser power. A solar laser is intended as a first step towards fast and low–cost interplanetary

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missions in deep space outside the Solar System, as well as a guide for objects orbiting the Sun. The big challenge faced by Starshot (2016) was designing a laser for propulsion. It requires ground–based laser arrays of 1 km^2 surface area and 100 GW, which would be by far the most powerful laser constructed on Earth. Also, a number of ground laser arrays with less power were suggested – (for sail 1–10 m wide), ≈ 100 kW. One such laser array could launch multiple times, potentially a fleet of small probes, each with different equipment to their destination. Essentially, it is an initial capital investment which, once built, serves as a launch pad. We also face the development of new probe models for individual users that usually do not have access to space, and could now spend only a few thousand $ to start a proper mission of deep space exploration. The mission cost then consists of: mass production of probes, which can be reduced to ≈$100 per unit, and launching them to orbit, for less than $100 per probe. The mass of ≈1 g previously considered for interplanetary laser sails, has now increased to 100 g, which is comparable to a typical cell phone. The assessment is made for instruments on the platform. The "Probe–100g" can be equipped with required components: spectrometers, accelerometers, particle detectors, cameras including magnetometers, probe etc. – all key elements for conducting a scientific mission in deep space. For sail materials, silicon or boron nitride is suggested, while ≈ 10cm width should be sufficient.

Laser arrays at the scale of 100 kW are already developed. The U.S. military etc, in 2020, the U.S. Navy's littoral combat ship USS Little Rock was equipped with a 150 kW laser. Prices of large laser systems gradually fall; lately at a rate of 1 kW for less than $10,000, which is an important reminder because of optical telecommunications. A rough estimate is that a 1 MW laser pump could be constructed with less than $100 millions. Thus, the laser guided approach offers very low costs for future exploration of the universe. It is estimated that a 0.035 ounces (1 ounce = 28.35 g) solar sail with a 4 inch surface area (1 inch = 2.54 cm) propelled at speed ≈180,000 km/h would reach Mars in 20 days, compared to 200 days of NASA; Jupiter in 120 days, compared to five years for NASA probe Juno; Pluto in less than 3 years away, compared to 10 years, for NASA ship New Horizons; and 100 times farther from the Sun for 10 years, compared to the distance that took almost 30 years for NASA spaceship Voyager 1. It would be really exciting to see a student sending his own science probe to Jupiter. The mystery of how black holes collide and merge is beginning to unravel. The study follows a kind of "paleontology" for gravitational waves to explain these phenomena. Stephen Hawking warned: "Human kind may have less than 600 years to leave the planet. If humanity does not become a truly space species in the next five centuries, we may become extinct". It is stated: "Wild 3D–printed space habitat prototype designed to fit Starship lands in Switzerland 1st commercial staged rocket passes hot–fire milestone". There are many more titles related to lasers and their role in the cosmos and solar needs and activities in the world under following titles: Places to live [21–27].

5. PLACES TO LIVE

Astronomers say rocky exoplanet may be the first potentially habitable world outside our solar system. The latest moon photos from NASA's Orbiter Low lunar probe are reflected along the margins of Lassell G and Lassell K.

6. LASER EFFICIENCY

The issue of laser efficiency is something that has been noted since the beginning of the first maser, but today it is still much improved in many types of old or newly developed lasers. The general approach was that when the Nd^{3+}: YAG and CO2 lasers went up over 30%?!, the scene started much better. However, there are various definitions of the efficiency coefficient. Some start from quantum, some from usual rations output/input, some are obtained as a product of subsystem parts and their efficiency, and it would be relatively unprofessional to ask that it be reduced to the same in a short material. It can also start with attitudes: carrier concentrations and energy for their level change; lasers without population inversion, by pump type source comparison, comparison of one active material to others.

With semiconductors lasers it is very impressive that it was done from miliparts of %–100% according to starting from the usual etc. For many of them, the efficiency is only expressed in quantum approach. There is also many data about comparisons of various lasers as in [28–37, 41–52, 55–58].

Speaking of efficiency, there are many papers comparing different types of lasers not only in output efficiency but in terms of the task they perform /crystals under low–power laser diode end–pumping. Output power dependencies on the pump power and the pump wavelength of these diode–pumped solid state lasers were investigated. The high Nd^{3+} concentration of the Nd^{3+}: KGW samples used in our measurements as well as up–conversion and exited–state absorption processes in Nd^{3+}: KGW cause the reduced laser output power dependence on the pump wavelength which was experimentally observed. At pump levels up to 270 mW, a slope efficiency of η_{sl}≈46% was reached for the Nd^{3+}: KGW laser. Nd^{3+}: KGW microchip laser operation with a slope efficiency of η_{sl}≈50% was demonstrated. Thermal lensing in Nd^{3+}: KGW at pump powers up to 3 W was observed.

Efficiency of the fiber laser design is significantly higher than that of the flashlamp–pumped: YAG laser, because the emission spectrum of the diode laser used for laser pumping. There is a very varied scale of efficiency definitions, coefficients, different definitions for efficiency coefficients from quantum to partial, which regulate the passage from one component to another, the process in the formation of stimulated emission (amplification and generation). In Tables 1 and 2, some of most common types, the performances of some most applied laser today also, but from first laser days, are presented. In Figure 5, various types of semiconductor lasers are developed from classical diode to quantum dot–types, etc. [30, 51, 53].

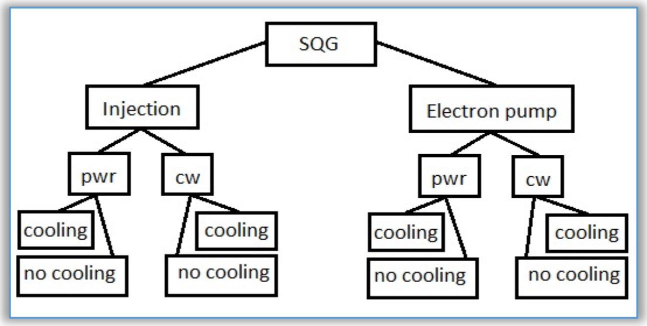


Figure 5. Semiconductor laser types; SQG semiconductors quantum generators, pwr–pulsed, cw–continous working regimes, respectively

Table 1. Comparisons of parameters for solid state common lasers

	Cr_3+:Al_2O_3			Nd^{3+}:Yag			Nd^{3+}:Glass		
	Free gen.	Q switch	cw	Free gen.	Q–switch	cw	Free gen.	Q sw	cw
W *,l, nm	693	693	693	1.064	1.064	1.064	1.058	1.058	1.058
Threshold, 300K, J	100	150…250, 5.5x75mm	2…5kW	5 5x60 Mm	10 5x60 mm	0.5kW	10–25 1 mm 0x80	20–50 10x80 mm	2kW
Energy/Power, J	1–1.5 5.5x75 1500 35mm	0.1–1	–	10 3.5x150	0.05–0.15 5x50	>200W	0.5–1000 45x600	<1.5 10x80 mm	–
Coef.effic. %	1.0	<0.1	–	–	>1	0.5–0.8	5–6	<0.04	–
Spec. energy Active mater., J/cm^3	0.8–2	0.13	–	0.85	0.15	–	1.0	0.25–0.3	
Freq. repetit, Hz	≈10	≈10	–	kHz–100MHz	kHz–100MHz	–	10	10	–
Active material sizes	240–350	240–350	240–350	150	150	150	1200	1200	1200
Therm.cond. Cal/(g Kcms)	0.55–0.66			0.03			0.02		
Price ,rel units	1			2			0.1–0.2		
Optimal detector	PM*		PM*	APM**		APM**			APM**

PM*–fotomultiplier APM**–Avalanche photodiode

Table 2. Parameters of Nd^{3+}:Glass in Q switch regime

Model in 1976.	Max pulse energy, J	Power, W	Repetition frequency, Hz	Pulse, ns	Divegency, mRad	Pump energy, kJ	Cooling	Kkd
LTIPČ–1	2	10	0.1	15	0.5	4	H_2O	0.05
VD–160,Biorad	3	10^{10}	1/60	30	0.2			0.1
VK–320,Biorad	50	2x 10^{10}	5/60	6	1			0.12
VK451,Biorad	100	2x 10^{10}						0.33
VK640,Biorad	250	2x 10^{10}						0.3
VK641SBiorad	650	2x 10^{10}	1/480		1.0			0.4

Kkd– efficiency coefficient

In references very many comparisons of quantum efficiency and total efficiency for semiconductor materials exist (18) pumped by flash lamp, other laser, nonlinear way, electronic beam pumped etc, and it can be seen that it is from some % up to 00%, Tables 3 and 4. It could be interesting to present only view of efficiency for photocathodes for common quantum generators wavelengths (or ranges), Table 5, Figure 6.

Table 3. Wavelength and pumping methods of semiconductors based on various materials

Materials	Wavelength, nm	Injections p–n transitions	Electron beam pumped	Optical pumped
ZnS	320		+	
ZnO	370		+	
CdS	490		+	+
GaSe	590		+	
CdS_xSe_{1-x}	490–690		+	
CdSe	680		+	
CdTe	780		+	
$GaAs_xP_{1-x}$	630..880	+		
GaAs	840..900	+	+	
InP	500	+		
$InP_{1-x}As$	850	+		
GaSb	1500	+	+	+
$InP_{1-x}As_x$	900…3100	+	+	+
InSb	5200	+	+	+
Te	3648		+	
PbS	4260		+	
PbTe	6500	+	+	+
PbSe	8500	+	+	
$Hg_xCd_{1-x}Te$	3700…4100	+		+
$Pb_xSn_{1-x}Te$	6500…13500			+

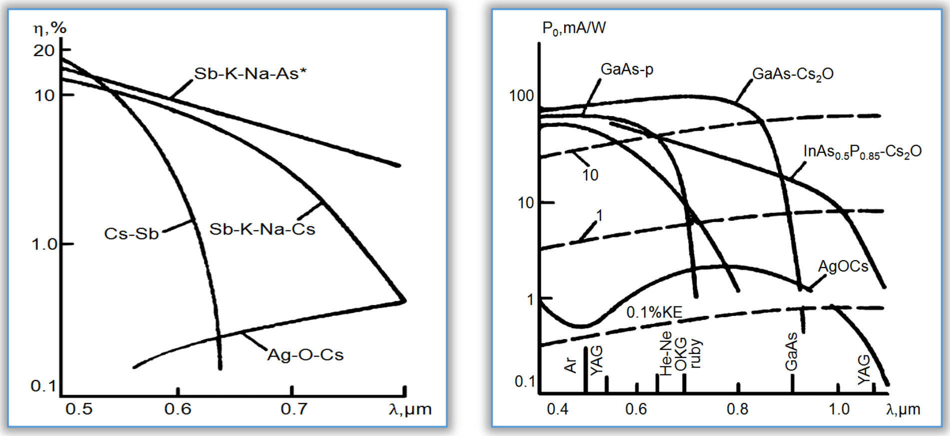
Table 5. Maximal quantum efficiency for various photocathodes for common quantum generator

Tip	λ Nm	Optimal Photocathode	Max effic., η	Opt. photocath. η %	Max η, %
Ar+:ion	430–500	GaAs–Cs_2O	25	Cs–Sb	18
YAG, SH*	530	"		Cs–Sb Sb–K–Na–Cs Sb–K–Na–Cs	13
He–Ne	630	"		Sb–K–Na–Cs*	–
Cr+:Al_2O_3	690	"		Sb–K–Na–Cs*	5
GaAs	905	"		Ag–O–Cs	3
Nd^{3+}: YAG	1060	$InAs_{0.05}P_{0.15}Cs_2$	0.8–1.5	Ag–O–Cs	0.04

*SH–second harmonic

Table 4. Wavelength and pumping methods of semiconductors based on various methods

Pump type	Max. energy output	Pulse length	Max. pump density	Max. radiation power	Active layer thickness	Special demands
		sec	W/cm^2	W	cm	
Electron beam	$\sim\hbar\omega/(3E_g)$ ~0.3	$10^{-8}-10^{-6}$	10^7-10^8	10^6	$10^{-4}-10^{-3}$	
Optical excitation (mono–photon)	$\hbar\omega<\hbar\omega_p$	CW generation $10^{-8}-10^{-7}$	10^7	10^5		$3E_g<\hbar\omega_p$
Optical excitation (two–photon)	$\hbar\omega<2\hbar\omega_p$	$10^{-8}-10^{-7}$	10^9		$10^{-2}-10^{-1}$	$3E_g<2\hbar\omega_p$
Injection	$\hbar\omega/(eU)$ ~0.1	CW generation $10^{-8}-10^{-7}$	10^4-10^5	~10 10^2	$10^{-5}-10^{-3}$ 10^{-2}	1) Electro–conductivity 2) Injection contact 3) Electrical contact
Breakdown	$\sim\hbar\omega/(3E_g)$ ~0.3	$10^{-8}-10^{-7}$	10^6	10^2	$10^{-4}-10^{-3}$	1) Electrical contact 2) Long time 3) Non–stationary conditions



(a) (b)

Figure 6 a) Quantum efficiency η_λ and b) spectral sensitivity P_λ versus λ.

Quantum efficiency is evaluated as: η_λ= 0.12 S/λ, η_λ–quantum efficiency, %, $S_\lambda(P_\lambda)$–spectral sensibility, mA/W, λ–wavelength; For 1mW/W, and 340nm, η=0.3% and for S 10mA/W 1.2%.

For solid state lasers as ruby, efficiency is obtained by multiplications of subsystems efficiency connected to mirrors and other components.

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Coefficient of efficiency for ruby laser is evaluated as products of some subsystems including mirrors, plates, other components optical, etc.

Derivation of the generalized expressions for the lasing conditions for the *n* level system and for the stimulated transition between the levels *i* and *j*

Access to quantum generators can be done in several ways depending on the level of other knowledge. There are many types of quantum generators according to the type of material, according to the area in the electromagnetic spectrum, according to the main interests that are sought. If we approach these processes/stimulated processes without discussion and just accept that both stimulated and spontaneous processes are possible. Only a few types of approaches can be listed, among which are:

a) The lowest level through equivalent schemes

b) Level by electromagnetic approach with negative gain involving Maxwell's equations and search for operating threshold, gain, generator and amplifier,

c) The next levels of access are with the inclusion of classical and quantum accesses, as opposed to radiation and active material

d) Various paths based on stricter quantum approaches would also follow.

Here we will focus on the part that involves rate equations, where we operate with the probabilities of transitions up and down and state that there is always a spontaneous and stimulated transition/induced transition. Note that nevertheless of definition of quantum generators efficiency and lasing regime in general, the population inversion between two chosen levels $N_{higher} > N_{lower}$, has to be obtained; or difference between two lasing levels is one of principal conditions.

At this point we shall list the equations and give some of the paths that are found with the most references, but with other formalisms. An educational approach proposed by Einstein, (indicated by the coefficients *A* and *B* with suffixes and prefixes), has intuitively admitted so far that there are spontaneous transitions in addition to the induced ones. This thermodynamic approach is narrower than starting from probabilities and subsequently creating more possible types of transitions, which are contained in the given formalistic description. Einstein's coefficients *A* and *B*, for spontaneous and stimulated transitions, will only be determined for two levels *m* and *n* and defined with respective symbols [31, 35, 36, 41, 45, 47, 48, 54–58].

The connection with other approaches, stated here for two levels *m* and *n* and defined with labels, is:

$$W_{mn} = W_{mn}^{ind} + A_{mn},\ \ m > n \tag{1}$$

$$W_{mn} = W_{mn}^{ind},\ \ m < n \tag{2}$$

$$\delta_{mn} = \begin{cases} 1, & m = n \\ 0, & m \neq n \end{cases} \tag{3}$$

For n levels

$$\sum_{i=1}^{n} N_i = N \tag{4}$$

$$\frac{dN_i}{dt} = -N_i \sum_{k=1}^{n}\left(W_{ik}(1-\delta_{ik})\right) + \sum_{k=1}^{n}\left(N_k W_{ki}(1-\delta_{ki})\right) \tag{5}$$

A) 3–level system

For three level system explicit, where N_i–concentrations of numbers of "impurity" responsive for transitions (produced stimulated) emission

$$N_1 + N_2 + N_3 = N \tag{6}$$

$$\frac{dN_1}{dt} = -N_1(W_{12} + W_{13}) + N_2W_{21} + N_3W_{31} = 0 \tag{7}$$

$$\frac{dN_2}{dt} = -N_2(W_{21} + W_{23}) + N_3W_{32} + N_1W_{12} = 0 \tag{8}$$

From Equation 6 follows $N_3 = N - N_1 - N_2$. Using Equations 7 and 8 it is obtained

$$-N_1(W_{12} + W_{13}) + N_2W_{21} + (N - N_1 - N_2)W_{31} = 0 \tag{9}$$

$$-N_2(W_{21} + W_{23}) + (N - N_1 - N_2)W_{32} + N_1W_{12} = 0 \tag{10}$$

$$-N_1(W_{12} + W_{13} + W_{31}) + N_2(W_{21} - W_{31}) + NW_{31} = 0 \tag{11}$$

$$-N_1(W_{32} - W_{12}) - N_2(W_{21} + W_{23} + W_{32}) + NW_{32} = 0 \tag{12}$$

From Equation 11 follows

$$-N_2 = \frac{N_1(W_{12}+W_{13}+W_{31}) - NW_{31}}{W_{21}-W_{31}},\ \ W_{21} \neq W_{31} \tag{13}$$

Substituting into Equation 12 produces:

$$-N_1(W_{32}-W_{12})-\frac{N_1(W_{12}+W_{13}+W_{31})-NW_{31}}{W_{21}-W_{31}}(W_{21}+W_{23}+W_{32})+NW_{32}=0 \quad (14)$$

$$-N_1\left[W_{32}-W_{12}+\frac{(W_{12}+W_{13}+W_{31})(W_{21}+W_{23}+W_{32})-NW_{31}}{W_{21}-W_{31}}\right]+N\left[\frac{W_{31}(W_{21}+W_{23}+W_{32})}{W_{21}-W_{31}}+W_{32}\right]=0 \quad (15)$$

$$-N_1=\frac{W_{31}W_{21}+W_{31}W_{23}+W_{21}W_{32}}{W_{32}W_{21}+W_{12}W_{31}+W_{12}W_{23}+W_{12}W_{32}+W_{13}W_{21}+W_{13}W_{23}+W_{13}W_{32}+W_{31}W_{21}+W_{31}W_{23}}N \quad (16)$$

Further, it can be arranged to be more elegant in several ways, but the expression cannot be reduced.
High extraction efficiency is observed at the free–electron laser of the JAERI FEL group, but in general laser processing (laser cutting), power and frequency of repetition are important when analyzing of processing efficiency as well as dynamic regimes: CW or pulse regimes. The second mode is the mode of one pulse or repeated pulses. Here we will focus / stick to resonator processes and many other parameters, including the sophisticated task or common task.
Some kind of repetition of mentioned equations for *n* and three–level case explained have to be as follows.
Equations for each of the levels 1, ..., *n* would then be written in order obtained dN_i/dt *n* times and assuming that the sum of the values is a constant that corresponds to the number of impurity concentrations in a solid state laser, in a given matrix that is crystalline or amorphous (crystal or glass). Batch processing and bulky execution would not present any problem, because the equation would be added to the above system that the sum of concentrators/centers is constant and amounts to a constant value for a given free designed material. That's why only the case with 3 and 4 levels are free–stress presented but with different symbols and labels. We put our labels or modifications of expressions from the literature.
The complex n–levels systems can be reduced, if real material is defined and forbidden spectroscopic transitions i.e. neglecting low transition probabilities. Expressions for the 3–levels threshold follow from the selected possible transitions 3–1, 3–2 or 2–1. What would be sought from the literature (calculations) or obtained from spectroscopic data, along with the knowledge of allowed and forbidden transitions, shortens these cumbersome expressions in many models, but readers have to remember (or see many pages), until they understand why some terms have disappeared. In threshold searching, depending on the authors conceptions, ΔN is included, but the others physical performances (as efficiency, sections, gain, etc.) depend on reference.
For chosen 3–level system, 4– and 5–levels, threshold follows from the selected possible transition as was mentioned for three levels, or others in respective chosen transitions. Sometimes N_C–critical is defined as a threshold value. Some missing (calculations magnitudes) can be obtained from spectroscopic data, or calculated indirectly, along with the knowledge of allowed and forbidden transitions. All these operations shorten these cumbersome expressions in many places.

7. THE SEMANTIC ANALYSIS OF ENERGY, LASERS, EFFICIENCY COEFFICIENTS AND AMBIGUITY

Since this paper presupposes a certain degree of interdisciplinarity and multidisciplinarity [59], some attention will be given to certain key terms used in this paper, followed by linguistic, or more precisely, semantic and lexicographic analysis of these terms.
The focus of this part of the paper is on the lexemes: energy, laser, efficiency coefficients and ambiguity. Perhaps the most striking lexeme in this set is exactly the lexeme ambiguity, since it seems to connect the linguistic side of the elements of the above–mentioned set and their stylistic contribution to the overall discourse at play. Let us look at their possible connections. According to WordNet 2.1 [60], the semantic unit energy has 6 senses:

- energy –– ((physics) the capacity of a physical system to do work; the units of energy are joules or ergs; "energy can take a wide variety of forms");
- energy, vigor, vigour, zip –– (forceful exertion; "he plays tennis with great energy"; "he's full of zip");
- energy, push, get–up–and–go (enterprising or ambitious drive; "Europeans often laugh at American energy");
- energy, muscularity, vigor, vigour, vim –– (an imaginative lively style (especially style of writing); "his writing conveys great energy"; "a remarkable muscularity of style");
- energy, vim, vitality –– (a healthy capacity for vigorous activity; "jogging works off my excess energy"; "he seemed full of vim and vigor"); and

— Department of Energy, Energy Department, Energy, DOE –– (the federal department responsible for maintaining a national energy policy of the United States; created in 1977) [60].

However, the situation seems to be quite different in case of the lexeme 'laser', which is simply defined as: 'laser', optical maser (an acronym for light amplification by stimulated emission of radiation; an optical device that produces an intense monochromatic beam of coherent light) [60].

Based on these definitions, the semantic unit energy is connected with human and human–like features and vitality of human–beings, even though it mainly refers to vigor, and primarily to the capacities of different physical systems.

The semantic unit efficiency has two senses:

— efficiency –– (the ratio of the output to the input of any system);
— efficiency –– (skillfulness in avoiding wasted time and effort; "she did the work with great efficiency"), while the semantic unit coefficient has only one sense: coefficient (a constant number that serves as a measure of some property or characteristic) [60].

Finally, the semantic unit ambiguity has two senses:

— ambiguity –– (an expression whose meaning cannot be determined from its context);
— ambiguity, equivocalness –– (unclearness by virtue of having more than one meaning) [60].

What is common here belongs to vagueness and ambiguity in some contexts. This problem can be resolved by including larger corpora [61–65] or by including specific algorithms for treating ambiguity [66–70].

8. CONCLUSION

The paper analyzes the role of quantum generators in connection with energy sources and overlapping with the field of fusion, thyrotrons and other types of energy. In connection with nuclear or chemical energy, many tasks can be found particularly related to bio–energy in the previous irradiation of seeds and growth promotion, isotope selection or in the process of removal (concentration of nuclear fallout), and removal of the danger of space debris. Efficiency is a complex question, starting from its definition to the efficiency of a particular type in relation to the input (energized by the pumps) and the output energy of the laser beam. Its calculation and evaluation depend on many factors, and also on the formalism adopted in a certain area.

On the internet, a lot of discussions concerning solutions of future survival can be found, followed by diverse questions of energy efficiency. The pumping can be from a solar, nuclear electron beam, nuclear particles, and other quantum generators; it is in a philosophically correct direction because it goes in the direction of energy of a lower quality to a higher one. Particularly interesting is the set of challenges dealing with the problem of survival, searching for other Earth–like planets, sending laser sails to probe the Cosmos, and more is considered. From an educational point of view, providing derived expressions for *n*–th level systems helps to systematize and prepare for various combinations and approaches that, along with five laser's equations, may give at least the first answer about the evaluation of the transition from level *j* to l and the like, i.e. conditions and connections with transition probabilities that are evaluated by appropriate theory or from spectroscopic data.

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