Towards abundant energy without pollution

LASER NUCLEAR FUSION

HOW TO ELIMINATE GLOBAL WARMING

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THE DEADLY THREAT OF GLOBAL WARMING

FINDING A RADICALLY NEW WAY TO PRODUCE ENERGY IS VITAL

Transport, heating and industry all require energy which , for the most part, is produced by burning oil and gas. This combustion generates huge masses of carbon dioxide CO_2 which absorbs the earth's radiation and results in raising its temperature. This greenhouse effect produces global warming which will make life on earth impossible to sustain over the coming centuries.

We must reinforce our use of renewable energies and ways of saving energy. This will however not be sufficient to resolve the serious problems posed by our huge energy needs for heating, transport and industry.

A radically new method of producing energy, one which does not use carbon, is therefore essential to man's survival.

Comparison of methods of energy production in france

In order to demonstrate some simple ideas, we shall look at the example of France. This example will enable us to draw conclusions which are valid for the whole world.

The unit which is widely used to evaluate energy consumption is the TEP or « Tonne Equivalent Pétrole ». this is the amount of energy produced by the combustion of a ton of oil. Since each year we consume a vast amount of energy, the equivalent of a huge number of tons of oil, we measure this in units called Megateps. Each megatep is equal to one million TEP.

Coal	6,12 Mteps
Oli	72,15 Mteps
Gas	35,44 Mteps
Electricity	36,44 Mteps
ENRT (renewable energies which produce heat)	10,47 Mteps
Total	161 Mteps

French energy consumption in 2005 by production sector

The total amount of energy consumed in France is 161 Mteps : 70 % is produced by the combustion of the carbon contained in coal, oil and gas. This results in several million tons of CO_2 being poured into the atmosphere and this in turn is responsible for global warming on a disastrous scale.

In order to limit the production of CO_2, we might consider increasing the amount of electrical energy produced by nuclear and hydro-electric power stations which currently produce 36,4 Mteps. Twenty per cent of this energy is supplied by hydroelectric power stations. These however will not be able to increase their production because the most suitable sites are already in use. In order to increase the amount of electrical energy, we would therefore have to construct new nuclear power stations.

These power stations use nuclear fission of heavy atoms such as Uranium. French power stations are technically highly reliable, and their use has so far not resulted in any serious accident.

Nevertheless, it must not be forgotten that their exploitation could lead to an explosion which would have widespread and serious consequences for public health. That is what happened at Tchernobyl in Ukraine. Another point to consider is that these power stations generate radioactive waste which remains dangerous for thousands of years. They also require fuel which is not found everywhere on earth, and supplying them thus poses economic and political problems which are additional sources of serious tension in the world. The continuing construction of nuclear fission power stations can be envisaged for the next few decades in order to maintain current volumes of production. On the contrary, increasing their number in order to triple or quadruple our energy production would present unacceptable disadvantages.

At present, renewable energies produced by wind turbines, solar batteries and agriculture are being developed. These do not produce CO_2, so they do not increase the greenhouse effect. This is an essential advantage, and we should therefore further our efforts in this area. By developing renewable energy sources, we can hope to slow down the greenhouse effect, but they will not contribute enough to rid us of global warming.

In order to prevent global warming from making life on earth impossible, it is essential that during the coming centuries, we manage to develop a radically new means of energy production which would enable us to produce abundant energy for a relatively modest cost.

We shall show how laser nuclear fusion will provide us with a timely method of producing the energy we so vitally need. In order to understand this method, we firstly have to explain two basic laws of physics which lie behind energy production. These were discovered by Einstein in 1905 and Planck in 1900.

In 1905, Einstein demonstrated that an immobile mass contains a lot of energy

An immobile mass m contains energy:

$$W = mc^2$$

c is the speed of light

c = 300.000 kilometres per second

The masses all around us contain a huge amount of energy and this is largely sufficient for all of our needs.

It has been calculated that the equivalent of one year of French energy consumption is contained in an immobile mass of 100 kilograms. An essential conclusion can be drawn from this fact.

We do not lack energy. The masses around us contain huge amounts of energy which are vastly superior to our needs.

Our problem lies in finding a way to extract energy from matter in a form we can use. We shall see that this energy must be in the form of thermal energy, that is, heat, which will be transformed into mechanical and electric energies. These forms of energy will enable us to power cars, heat houses and supply our industries.

Einstein tells us where we can find energy. He does not however tell us how to make it appear in a usable form.

In 1900 Planck made a discovery which set us in the right direction to find out how to do this.

In 1900, Planck discovered the law of hot body light radiation

This led to the discovery of the granular structure of matter

When we raise the temperature of a piece of metal, it becomes red, then white. Planck explained this phenomenon by showing that light is emitted by ***hν*** grains in proportion to the frequency ***ν*** of the optical wavelength.

From this, Niels Bohr deduced that matter is made up of little grains called atoms.

We can deduce the size of a bell from listening to the sound it makes: a big bell makes a deep sound, while a small bell makes a high sound. The bell's spatial structure can be deduced from the radiation of its sound waves.

Planck discovered the radiation of matter. From this, Niels Bohr deduced that matter is made up of atoms whose spatial structure he was able to determine.

The simplest of atoms is that of Hydrogen, whose structure is shown in **Fig.1.**

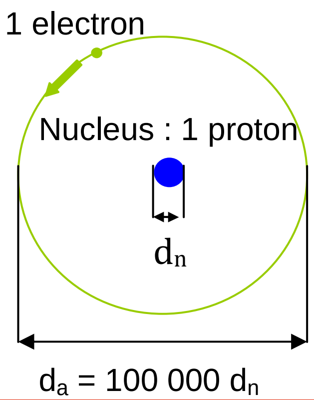

Fig.1 Hydrogen atom

$d_n = 10^{-13}$ cm $\qquad d_a = 10^{-8}$ cm

At the centre of the Hydrogen atom is a nucleus made up of an elementary particle, the proton. It carries an electric charge **e.**

An electron carrying an electric charge – *e* rotates around the nucleus.

The proton's mass ***M*** is 2000 times greater than the mass of the electron ***m*.**

The diameter of the nucleus d_n is 100.000 times smaller than the diameter of the spherical trajectory ***da*** of the electron inside the atom.

To evaluate the energy of the charge on the nucleus, we need to calculate the energy required to carry a positive charge on a sphere with the tiny diameter d_n. It appears that the smaller d_n, the greater the energy necessary. More energy will thus be required to carry an electric charge on the nucleus with diameter d_n than on the sphere with diameter d_a on which the electron is found.

A practical unit for evaluating the types of energy in question is the electron/**V**olt (**eV**). This is the energy of a charge ***e*** to the potential of one volt.

It appears that the energy of an electron moving round a sphere with diameter d_a amounts to approximately 1 **eV**.

The energy of the charge of a proton in the nucleus is about 1 million **eV**.

We can immediately deduce that it will be much easier to make the electrons of two different atoms interact than to make the particles of their nuclei do so.

The structure of atoms

The Hydrogen atom has the simplest structure, shown in **Fig.1**

Deuterium and Tritrium atoms have a similar structure, shown in the diagram **Fig.2**

Deuterium (heavy Hydrogen)

Tritium

Fig.2 Deuterium and Tritium Atoms

The neutron and the proton are similar in mass.

The neutron carries no electric charge.

The nucleus of Deuterium contains one proton and one neutron, the nucleus of Tritium contains one proton and two neutrons.

Deuterium and Tritium are isotopes of Hydrogen. The proportion of heavy water D^2O in ordinary water is $\frac{1}{5000}$. Each litre of water thus contains 0.2 milligrammes. Deuterium can be produced by electrolysis of water. This is not the case for Tritium which occurs far less frequently.

The nuclei of the other atoms contain a defined number of protons and neutrons.

The Carbon atom contains six protons and six neutrons, while Oxygen contains eight protons and eight neutrons.

The Carbon atom is shown in **Fig.3**. The Oxygen atom is shown in **Fig.4**.

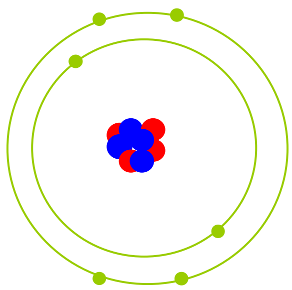

Fig.3 Carbon Atom

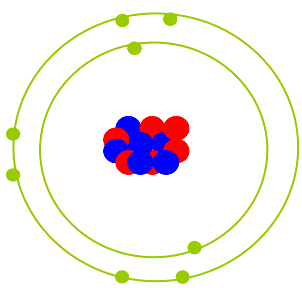

Fig.4 Oxygen Atom

Reactions between atoms A and B form molecules AB

The structure of the AB molecule depends on the form of atoms A and B. Molecules have very differing structures.

Calculation and experiments show that if the accumulation of electrons is brought up to eight by an appropriate association of atoms, the energy of the molecule and thus its mass, is minimal. In this manner, the single peripheral Hydrogen electron unites with the six peripheral Oxygen electrons to form the molecule H2O**.**

Fig. 3 and **Fig.4** show that Carbon has four peripheral electrons and Oxygen has six.

Fig. 5 shows how C and O2 can join to form a CO2 molecule whose energy, hence its mass, will be weaker than the mass of C and O2 when these are separate.

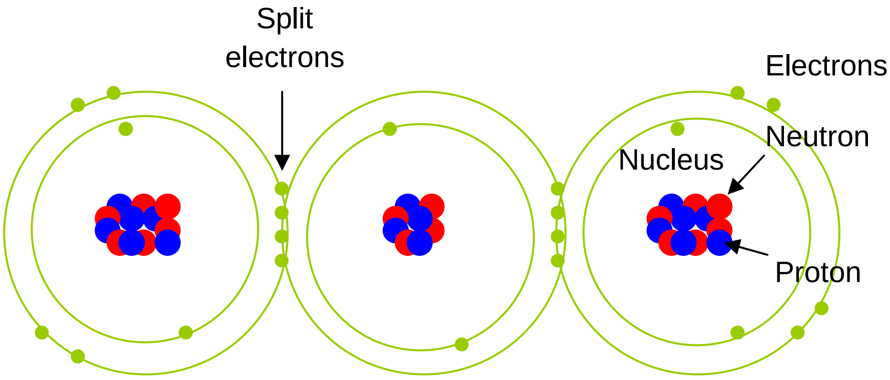

Fig.5 CO_2 Molecule

The reaction $C + O_2 \longrightarrow CO_2 + 4$ Ev produces energy.

This is because the CO_2 molecule has a lower level of energy than $C + O_2$. The result of the reaction is a reduction in the mass ***m*** of the combustibles **$C + O_2$ by Δm**. Thus, energy is produced

$$W = \Delta m \cdot c^2$$

HOW ENERGY IS PRODUCED

To produce energy, two bodies A and B are combined to make up one body AB. If the mass of AB is lighter than that of A+B, energy will be produced. This results from Einstein's law. If **Δm** is the difference between the mass of A+B and AB, the energy produced will be given by the relationship between the two.

Taking into account the structure of matter explained previously, we can predict that there will be two classes of reaction between the two bodies A and B: chemical reactions which involve only the electrons, and nuclear reactions which are determined by the nuclei.

Chemical reactions between electrons

A reaction can result from a shift in the position of electrons without involving the nuclei. Chemical reactions occur frequently in everyday life, for example, burning wood.

We have said that the energy of electrons is very weak. We can thus predict that the energy produced by an atom will also be weak. Calculation shows this energy to be about one tenth of a billionth of the energy mc^2 contained in the immobile mass of the matter of bodies A and B combined.

We have seen that the energy mc^2 required by France for one year is contained in a mass of 100 kilograms of matter. In order to produce energy, we therefore require a combustible mass 10 billion times greater than 100 kilograms: 1000 billion kilograms, or 1 billion tons. The huge amounts of CO_2 resulting from the production of this energy will be expressed in hundreds of millions of tons; certainly enough to cause disastrous climate change.

Global warming is caused by the production of CO_2 which in turn results from the very structure of matter; it is thus fundamentally unavoidable.

Nuclear fission and nuclear fusion: reactions between nuclei

We are thus led to consider using reactions between nuclei. We have seen that the energy in the particles of the nucleus is approximately one million times greater than that of the electrons. This is because of the small size of the nucleus. We can deduce that a nuclear reactor will produce about a million times more energy per unit of mass.

If 1 billion tons of matter were required to produce energy by chemical reaction, only 1000 tons of matter would be required to produce the same amount of energy by nuclear reaction. There would be no production of CO^2, therefore no global warming.

Nuclear reactions therefore represent enormous progress. However, they are harder to create than Carbon combustion.

There are two categories of nuclear reaction:

- Reactions involving heavy and fragile nuclei such as Uranium. These are **nuclear fissions**.
- Reactions between lighter elements such as Hydrogen, Deuterium, Tritium. These are **nuclear fusions**.

Nuclear fission power stations are feasible today. We have seen that they have great disadvantages, and it seems impossible that a sufficient number of these power stations could be built to prevent global warming.

Today we have managed to use fusion to manufacture the incredibly powerful H bomb. We have not yet managed to construct electrical power stations which use nuclear fusion.

To create energy using nuclear fusion, matter must be brought to a high density and temperature, while still respecting all the safety and financial constraints involved in building and running an electrical power station.

One method takes advantage of the properties of magnetic fields, using these to compress matter. This is what is currently being done by the international project ITER (International Thermonuclear Experimental Reactor) in Cadarache.

Another method uses a laser beam to compress and raise the temperature in a small enough sphere, and then recuperate the energy produced. This is laser nuclear fusion. I proposed this concept in November 1962. General de Gaulle immediately saw its potential and accepted it. Since that time, I have participated in work on this project, and I frequently meet the research teams involved at international congresses.

PRODUCING ENERGY BY LASER NUCLEAR FUSION

Thanks to new method of producing laser impulses, resulting in much shorter impulses than those obtained previously, by Gérard Mourou, it seems highly likely today that we will obtain the ignition of reactions before 2025. Experiments in this direction are very promising.. The principle of this method of ignition is shown in Fig.4.

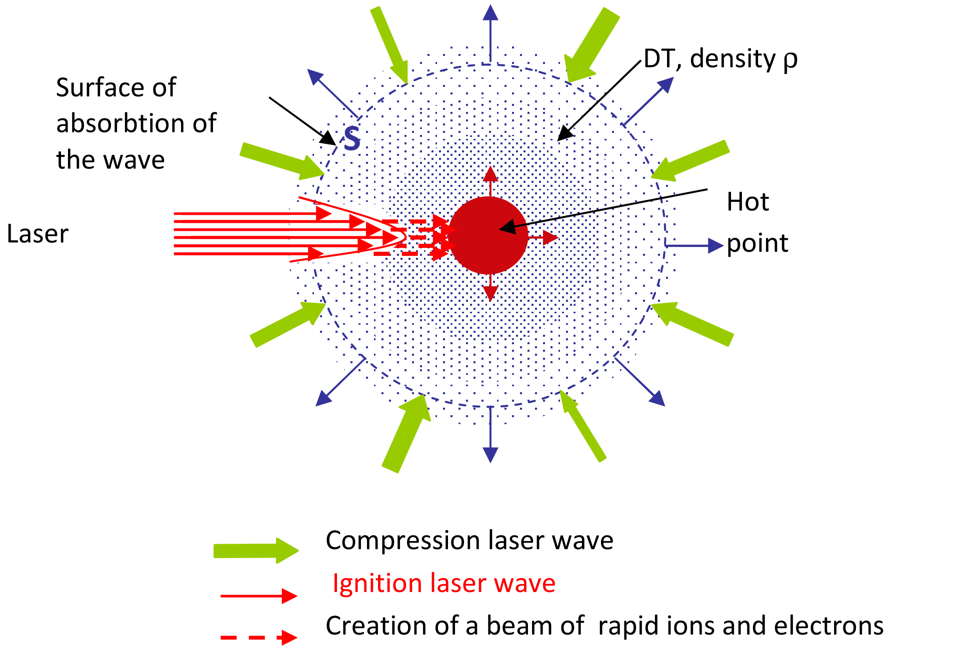

Fig.4 Principle of rapid ignition enabled by very short impulses.
« The Physics of Inertial Fusion » by Atzeni and Meyer-Ter-Vehn(2004)
Oxford Science Publications

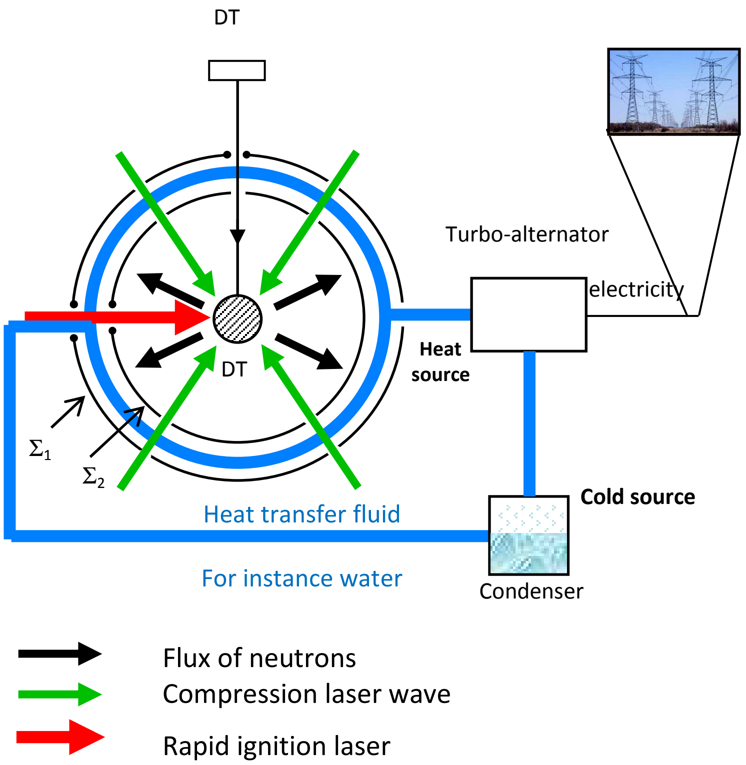

Fig.5. Diagram of the structure of an electrical power station which uses laser fusion

The energy produced by the fusion reactions is transported by a flow of neutrons generated by those reactions. This flux is absorbed by the heat transfer fluid, such as water, that circulates between spheres Σ_1 and Σ_2. This heat transfer fluid supplies the hot source of a turbine that drives an alternator which generates electrical energy. Ten times per second the DT sphere emits sufficient energy for the station to produce 1 Gigawatt (1 billion watts), just like current powerful electric stations.

Once rapid ignition has been obtained, I am convinced that about fifty years hence we will be able to build electrical power stations producing huge amounts of energy for a modest price. This conviction is based on my own deep personal experience in the field using the relevant technologies.

An essential part of the station is made up of an ignition system that produces the luminous flux shown in red in Fig.5. It will be constructed using the technologies of mass produced electronic circuits which have enabled us to progress from the incredibly heavy 1955 Hertzian cables to the mobile phones of today. The system will contain large masses of glass traversed by huge laser flux .

Around 1955, I was the in charge of the operations carried out by the teams which built the Hertzian cables weighing ten tons, from Paris to Lille and Lyon. From 1962 to 1970, I directed the teams which transformed those heavy systems into the light and reliable mobile phones we all use today.

My laboratory in Marcoussis created the high power laser technology which was the basis of research into nuclear fusion. We managed to obtain glass resistant enough to reach the huge power which is essential. Since then, I have been following all the progress made in this field.

In addition, the station's structure does not require any material subject to insurmountable constraints We therefore do not anticipate any great difficulty in building the station.

Current technologies use Carbon, which is disastrous. Laser nuclear fusion uses Deuterium, heavy Hydrogen. This is found in sufficient quantities in water all over the earth, and creates no dangerous waste.

Today it is almost certain that before the end of the century, laser fusion will provide an abundant production of electric energy, without any pollution or risks for a relatively modest price. Deuterium, the combustible that will be used, is found in sufficient quantities everywhere on Earth.

This abundant electrical energy will make it possible to transform the CO_2,H_2O mix into a hydrocarbon which can be used to power cars and manufacture food for humans. No CO_2 will be produced, as the CO_2 taken from the atmosphere will be returned after the hydrocarbon has been burned. The cause of the greenhouse effect will therefore be removed and global warming, that is destroying life on Earth, will be eradicated.

Abundant electrical energy will allow us to generate optical energy very efficiently. It will become possible to produce a large amount of food by photolysis. This will eliminate hunger in the world.

MAJOR INFLUENCE OF CONFERENCES ON LASER NUCLEAR FUSION AT SAN FRANCISCO IN 2009 AND BUDAPEST IN 2010

In September 2009, the sixth IFSA (International Conference on Inertial Fusion Sciences and Applications) gathered 500 top level researchers from most of the countries in the world: the United States, France, Russia, Japan, China, Germany, England etc.

I have been attending these conferences since 1965: at that time only about twenty people were present, most of them French and Russian. These nationalities were the first to pave the way for this subject. The contributions at this latest San Francisco conference were very interesting and current situation can be summarized in the following points :

We have not yet managed to achieve the ignition of nuclear reactions in a sphere small enough for the energy thus produced to be exploitable.

Around 1990, Gérard Mourrou managed to obtain laser impulses whose duration could be a thousand times shorter than those currently in use.

Calculation and experience show that the electromagnetic energy of the incident wave on the small sphere is transformed into the energy of the electrons and ions of matter. These particles are projected at a speed approaching the speed of light.

Ignition occurs when we obtain a sufficient concentration of energy emitted by the laser. The impulses obtained by Gérard Mourou, far shorter than those obtained previously, are certain to reach the required concentration of energy.

Calculation shows that a suitable choice of the structure of the concentration will make it possible to obtain ignition with a relatively modest amount of energy. This will result in the possibility of constructing electric power stations for a wide range of applications.

At the San Francisco conference, I had long conversations about this question with the main American, Japanese and Russian leaders in the field, as well as others. They all confirmed their absolute certainty that ignition would be achieved thanks to the ultra-short impulses obtained by Gérard Mourou.

All agree that we must begin today to carry out work on planning and constructing the power station for producing energy. This could begin by work on constructing small spheres and their illumination by laser, elaborating the structure of the laser match and working on converting the energy of the neutrons produced by fusion into heat etc.

To clarify the meaning of the terms we use to define the evolution of the creation of a technology, we will consider the history of a technology that we know well that is the possibility of flying, that of aviation.

The first power tool having managed to leave the ground is *Eole* of Clement Ader. He completed a flight of about fifty meters October 9, 1890 in Castle Park Arminvilliers. This demonstrated the ability to fly a little heavier than air. That is what we call a proof of principle.

It now appears likely that this phase will be frank about 2040 for laser fusion.

On 13 January 1908, Henri Farman, on Voisin airplane makes at Issy les Moulineaux the first kilometer closed circuit. On 29 July 1909 Louis Bleriot crosses the Channel from Calais to Dover. We can consider that in 1909, we knew how to make a prototype and build many planes Many civil and military aircraft have been made immediately after 1910.

When we say that from a certain date we can build many electrical laser power stations, that means we've reached the level of development of aviation in 1910.

In the case of laser fusion, we say that the level of a prototype will likely be reached in 2080. If a major and priority effort is decided, this possibility could open as soon 2060.

If we begin today, we will be able to construct a first proof of principle of power station by 2040. This will enable us to act quickly to avoid the destruction engendered by global warming.

I think that this approach to dealing with the problem is completely in keeping with the challenge we are facing.

In my book "*Towards the end of global warming – abundant energy without pollution*" I explained that constructing a power station would certainly be achievable at a relatively modest cost.

Indeed, the diagram of the power station shown in fig. (5) shows that it is made up of two parts which function independently :

In one part, the match supplies the red arrow which represents the trajectory of the ultra-short laser impulse resulting in ignition.

In the other part, the energy of the neutrons produced by the fusion is recuperated and transformed into thermal and electric energy.

The match is an electro-optical system taking full advantage of the methods of circuit mass production which have resulted in cheap and reliable cell phones. We can be sure that the match will be efficient and reasonably priced.

The neutrons can be absorbed on a sphere whose radius may be as large as necessary. We anticipate no great difficulty in its construction.

The reason that we can be so sure about the construction of this power station is largely due to the fact that the ignition apparatus and the recuperation and transformation of energy are independent of each other. This separation means that the construction does not require materials which must have particular characteristics which are hard to find, for example, refined electronic properties and the capacity to sustain intense energy flows.

Obtaining the necessary efficiency will require powerful teams to undertake years of research in optronics. We now know which problems must be overcome. Now we have to set powerful, competent teams to work in order to solve these problems.

Some think that laser fusion is a utopian idea which could be useful one day, but not before centuries to come. This does not correspond with reality. The San Francisco conference has shown that an experiment demonstrating that it is possible to produce energy by laser nuclear fusion can be achieved probably towards 2040. Work with this aim in view has already begun.

In september 2010, at the *European Conference on Laser Interaction with Matter* (ECLIM) in Budapest , The prospects for ignition of nuclear fusion by laser were extensive. It appeared very likely that this ignition will be achieved over the next few years, probably first in Livermore, near San Francisco.

The date on which this technology will be available to a large extent depends on the concentration of resources towards the goal of producing electricity for the needs of the civilian economy.

Today this concentration is achieved in the USA in San Francisco. One can reasonably expect that the proof of principle will be carried out around 2040. The first prototype of fusion nuclear power station could be available in 2080. If a priority was given to this work it is not impossible to achieve this goal by 2060.

The possibility of producing high-energy accelerators through the interaction of short impulses with a plasma has been exposed. High-energy physics application require accelerators reaching energies increasingly large. Current methods require long and expensive accelerators. The short impulses will greatly reduce the length and do better and cheaper.

The conference emphasized the importance for basic research of the very large concentrations of energy allowed by short impulses. It intends to explore the structure of vacuum, creation of a pair of particles…

We know that in France the *Laboratoire d'Optique Appliquée (LOA)* directs an excellent example of its work to the prospects for short impulses.

L'Institut Lumière Extrême created by Gerard Mourrou at Palaiseau certainly get scientific results of major importance in this exciting new field.

The congress has opened a new perspective for international cooperation. This has been a joy for me to get many contacts with Germans, Czechs, Hungarians .I am convinced that many cooperation can be established between the European countries. The next European Congress of this nature will be held in two years in Warsaw. I plan to attend.

In my book "*Towards abundant energy without pollution. Nuclear laser fusion* "published in 2008, we find a presentation on the opportunities offered by the laser energy production. Forecasts that I presented in this book are entirely consistent with ideas expressed in this conference in Budapest.

HISTORICAL NOTE

In 1960 when he returned to power, General de Gaulle asked industry to encourage research. Back then, the *Compagnie Générale d'Electricité* was a powerful french company in the fields of electricity and electronics. It established a powerful Research Center in Marcoussis, near Montlhéry. I was part of the initial team, and was asked to come up with propositions that could lead the way to new technologies.

The laser had just been discovered, and I thought that by focusing the energy of a powerful laser on matter, we could obtain entirely new phenomena, particularly the control of nuclear fusion. A proposition on this theme was transmitted to General de Gaulle on November 22, 1962. He immediately accepted and asked us to contact the Military Applications Director of CEA-DAM (*Commissariat à l'Energie Atomique-Direction des Applications Militaires*).. The Director of the Physics Department, André BRIN took the lead of the operation. Limeil studied the interactions of the laser with matter, and Marcoussis developed the lasers requested by Limeil.

This cooperation between Limeil and Marcoussis was a great success. By 1967, our lasers were thirty times more powerful than all the others in the world. The President of the United States asked the General for France's help, which he granted immediately. This cooperation between the United States and France is still pursued today. In 1969, the Limeil Center carried out an experiment in laser fusion. This was done independently of the Russians, and can be considered as a world first of major importance.

In 1992, President François Mitterrand announced a moratorium on nuclear experiments. And in September 1996, Jacques Chirac decided the permanent cessation of experiments. Since a simulation program is in place to maintain control of the weapon and perform modelling experiments effected with a laser emitting 1 million Joules at the LMJ in Bordeaux.

Towards 1990, Gérard Mourrou proposed a method for emitting much shorter impulses than previously. The interaction of these very short impulses with matter is very efficient and lead way to the ignition of nuclear fusion in spheres small enough to be used with a view to producing energy.

England and China have recently made great efforts in this area, joining France, the United States, Russia and Japan which have been working on the subject for the past forty years.

SOCIAL AND ECONOMIC PROSPECTS

Prospects in France

The essential importance of civil applications of laser fusion

Since 1962, thanks to their creativity and to General de Gaulle, the French have made a large contribution to opening up new paths in science and technology with laser nuclear fusion.

It's essential that their efforts will result in returns in the economic and social fields.

Today it is very likely that we could construct a proof of principle of a electric power station run by laser fusion by 2040. It would be fuelled by Deuterium and heavy Hydrogen both of which are found in sufficient quantities in water all over the earth. This energy would be reliable and its cost reasonable. Moreover, it would produce no dangerous waste.

Since 1993, the French have pursued huge efforts in the area of laser fusion. These have been centred on the 1 Megajoule laser under completion in Bordeaux inaugurated on 14 October 2010 by Nicolas Sarkozy

For the past twenty years or so, it seems that humanity has finally decided to organise a more peaceful life on the planet. Current methods of energy production result in global warming which is threatening man's survival. We need a radically new method which will provide abundant electrical energy without pollution and at a reasonable cost by using a fuel which can be found in sufficient quantities everywhere on earth. We know that laser fusion will enable us to build electric power stations which respect these conditions.

It thus appears appropriate that French investments into laser fusion should be directed in priority towards electric energy production for civilian ends.

We must understand that giving priority to civil applications does not mean neglecting research into increasing the efficiency of the H bomb.

Of course, we should not neglect the importance of having an H bomb which can cause enormous destruction; This can be a force of dissuasion against enemy attack, and remains an essential element of our national defence whose creation was decided by General de Gaulle. For one thing, this is a guarantee of our independence. Remarkable scientific research enabled the French to construct this weapon. Robert Dautray, in particular, played an important role in the struggle which lead to its development. Many French people feel that it is important to maintain this weapon in an efficient state because it safeguards the independence of their country.

The main difficulty of constructing a system of energy production is obtaining efficient ignition with the minimum amount of energy.

We have reason to believe that this is more difficult to obtain if the illuminated sphere is small, as for energy production, than if the sphere is large, as for a bomb.

Consequently research in view of civil applications will in all likelihood open possibilities for military applications. Conversely, it is less likely that research in view of military applications will open new possibilities for civil applications of energy production.

Producing energy through laser fusion, invented by the French, will enable them to provide an essential contribution to the elimination of global warming. This is coherent with other contributions made by the French to mankind in order to improve human culture and quality of life. It is highly desirable that France play this essential role in eliminating global warming enabled by the originality of French research. France also has the right to benefit from the enormous economic openings resulting from the construction of electric power stations for a reasonable cost and without pollution, fuelled by material sufficiently available all over the world. This would contribute to a decrease in unemployment at home, in a world of increasing competition.

Science should play an essential role in our culture. It contributes the joy of discovery of the amazing laws of nature. Experience shows that it is thanks to a deepening knowledge of the laws of science that mankind can survive; Science should thus have an important role in our lives, and in particular in the education of our young people.

We could draw their attention to the technological and economic perspectives which science opens up. Constructing these power stations will require people who are highly skilled in physics, mathematics, chemistry etc. Possibilities for employment in the control of laser fusion could be proposed each year to Universities, IUT and "Grands Ecoles" such as Polytechnique, Centrale, Supelec etc.

The decision to direct research in the domain of laser fusion towards producing abundant electric energy without pollution could be joined by measures which could bring about a new enthusiastic attitude in our country. We are aiming to serve mankind and ensure our survival. Such an aim is deserving of our utmost efforts and determination.

Worldwide Prospects

The world's most powerful countries are now aware of the great danger of global warming. Saving energy and increasing use of renewable energies are not enough to eradicate the greenhouse effect. It is essential to cut down on the combustion of Carbon, oil and gas that produce CO_2. A new method of energy production is indispensable. In most countries in the world, those who are in charge of directing technology are convinced that laser nuclear fusion is the way to reach our goal.

These last years, I have been talking to Chinese, Japanese, Russian, British, German and Italian decision makers. The Chinese have recently made great efforts, and the British are particularly dynamic, having initiated an international effort on the subject called HIPER (High Power Laser Energy Research). I believe that the whole world is beginning to realise the vital importance of getting involved with this field of research. Wide cooperation is developing between nations, and this leads us to genuinely believe that by the end of this century this worldwide effort will enable mankind to eradicate global warming and hunger in the world.

This subject will be covered in more detail in the book

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