Lasers could revolutionize the technology of uranium enrichment

by Laurent Rosenfeld

In April 1985, the U.S. Department of Energy (DOE) will make decisions on credit allocations for the construction of uranium isotope enrichment factories based on new physical principles. These facilities, unlike any existing enrichment plant, will use finely tuned lasers to achieve the enrichment of uranium isotopes necessary to provide fissile material— i.e., nuclear fuel.

In order to fuel most of the present nuclear power plant designs, natural uranium has to be enriched in its fissile (radioactive) uranium-235 content from 0.71% to about 3 to 3.5%. Because the two naturally occurring grades of uranium, U-235 and U-238, have essentially similar chemical properties, the enrichment process makes use of slight differences in physical properties; however, these differences are so minute that it has been impossible to directly extract any sizeable quantity of U-235 for industrial use. The uranium must be processed hundreds or thousands of times in isotope-separation element cascades.

Right now, there is a worldwide excess of enrichment capability (42 million separative work units—SWU—against a demand in 1985 of 39 million SWU), but these capabilities will be insufficient by the early 1990s. Enrichment facilities need to be large in size and represent enormous investments, requiring planning well in advance of coming on line. Therefore, the decisions taken by the DOE in April will determine the prospective enrichment capabilities of the United States and the rest of the Western world for decades to come.

Present enrichment techniques

So far, the bulk of uranium enrichment in the world has been performed by gaseous diffusion facilities. This process is used in the three large U.S. factories, in Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio, as well as in the large Eurodif factory in Le Tricastin, France, sponsored by a consortium of France, Belgium, Italy, and Spain. This process, which employs diffusion of uranium hexafluoride (U-235 hexafluoride is a little bit lighter and diffuses a little bit faster than U-238 hexafluoride) through several thousand porous barriers, is rather costly and consumes a lot of energy: about 9,000 kilowatt hours (KWH) are needed to produce the four kilograms of SWUs required to process 6 kilograms of natural uranium into 1 kilogram of 3%-enriched

uranium, which will in turn fuel approximately 265,000 KWH.

Another process has been developed more recently, ultracentrifugation of uranium hexafluoride. It is being used in the Urenco-Centec consortium factories of England, Germany, and the Netherlands. This process is slightly more efficient than gaseous diffusion; it requires fewer separative steps and about ten times less energy per separative work unit. It requires, however, large numbers of separative elements, because the production per element remains small. The traditional separative element is a chamber turning at a velocity of about 50,000 to 120,000 rotations per minute, which creates difficult problems of material resistance. The so-called fifth generation ultracentrifugation—still in the development phase at the Piketon, Ohio, experimental factory and elsewhere—implies even higher rotation velocities and requires the use of new materials such as composites, resins, and carbon fibers developed by the aeronautic industry.

Finally, a process developed in Germany in the 1970s (and then sold to Brazil) is uranium hexafluoride expansion in a curved nozzle. Heavier U-238 hexafluoride propelled at high velocity tends to be pushed more to the outside of the curved nozzle than U-235 hexafluoride.

The laser enrichment techniques

The new processes using lasers completely change the dimensions of the enrichment problem. The common character of the three cited processes is the use of bulk energy to play on a minute weight difference between the two uranium isotopes. The laser methods use directed-energy beams to differentiate between intrinsic atomic or molecular properties of the isotopes. Finely tuned lasers can differentiate so precisely between the two uranium isotopes that one separative step is more than sufficient to obtain enriched uranium at the required grade level. If correctly tuned on the excitation ray of one uranium isotope, a laser can in principle create much stronger physical differences between the two isotopes, differences which can then be used for separation.

Two main processes have been developed so far: One is atomic laser separation, *photoionization,* and the other molecular laser separation, *photodissociation.*

In the first process, uranium metal is vaporized at a tem-

perature of 3,000° Kelvin by electron bombardment; the U-235 atoms are then selectively excited by a finely tuned dye laser operating in the blue-violet part of the electromagnetic spectrum. This electronic excitation is brief (one ten-millionth of a second); a second, more powerful laser impulse, however, is used to give the excited atoms enough energy to trigger the expulsion of an electron (in some processes, even a third laser impulse is being used); the extraction of the ionized U-235 atoms is then accomplished by electric and magnetic fields. Using powerful tunable lasers in the ultraviolet spectrum would make the process easier, as atoms could be ionized with a single laser impulse; this, however, would probably require the development of industrial free-electron lasers.

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The second process uses a laser to dissociate a molecule of uranium hexafluoride. The infrared absorption spectrum of uranium hexafluoride shows considerable differences between U-235 and U-238, a 0.016 micrometer wavelength shift; this is the largest known type of uranium isotope differentiation. However, at usual temperatures, all molecules are already excited. So, the process can only be performed on a cooled-down (100° Kelvin) uranium hexafluoride gas, a cooling which can be done by supersonic gas expansion. A 16 micrometer infrared laser impulse can then selectively excite the U-235. This impulse could in principle dissociate the molecule, which only needs to absorb enough photons, but parasitical reactions tend to reduce the selectivity of the process. Therefore, one prefers to have this first infrared impulse followed by a shorter wavelength impulse in which one single high-energy photon does the dissociation work; a 308 nanometer ultraviolet laser is thus used to preliminarily dissociate the molecules excited by the infrared laser. At this point, the uranium hexafluoride molecule is broken down into a uranium pentafluoride molecule, which polymerizes quickly into a crystaline snow $(UF_5)n$, while the excess fluor is easily handled with hydrogen.

In the process presently being developed in Saclay, France, the original infrared impulse is supplied by a carbon-dioxide laser (wavelength 10.6 micrometers) associated with a Raman effect frequency converter bringing the output impulse into the vicinity of the required 16 micrometer ray.

Although it has the advantage of dealing with uranium hexafluoride, by now a technologically very well known product which seems easier to master than large quantities of uranium metal vapor, this photodissociation process has been abandoned for industrial development in the United States, which decided in April 1982 to limit laser isotope separation development to photoionization, a process which was slightly more developed at the time of the decision. The French CEA has continued exploring the two processes, and seems to obtain better results with photodissociation; the final French decision is to be taken in early 1986.

At least two other modern enrichment processes are being developed. One uses cyclotron resonance on a uranium-ion plasma; it is then sufficient to irradiate the plasma with an electromagnetic wave having the same cyclotron resonance as U-235 ions in order to deviate their trajectory and separate them. However, the process appears to be less selective than the laser processes and is technologically rather difficult to realize.

Let us also mention for reference the Chemex chemical process developed by the French Commissariat à l'Energie Atomique (CEA) announced by André Giraud in 1977 at the Salzburg conference of the International Atomic Energy Agency (IAEA). The process is now fully developed and uses the fact that U-235 is slightly more reductive than U-238. While cheaper than gaseous diffusion, technologically easy to master, and favored by the Carter administration at that time because it doesn't allow high enrichment factors and therefore cannot be used for producing military-grade uranium, this is a highly non-proliferant process, and its character does not seem a priority anymore.

Ultracentrifugation vs. laser photoionization

As far as the DOE's April 1985 decision is concerned, the competition has been progressively reduced to two processes: ultracentrifugation and photoionization. The former is technologically more traditional, although it still requires important development in material resistance; it will be preferred if prudence and a short-term view prevail. On the other side, laser enrichment processes are scientifically and economically more forward-looking, but therefore require more technological development.

Laser isotope separation is no doubt fundamentally more efficient and should eventually triumph unless even more efficient processes are developed. Disregarding possible technological application problems, the coherent directed energy of a laser creates a qualitative phase change and thus organizes matter much better for further processing than the bulk random kinetic energy used in ultracentrifugation. This

advantage translates efficiently in the expected performances of the two processes.

While the costs and investments required by the two processes are of comparable magnitude, about $20 per SWU against $150 with gaseous diffusion, one of the yardsticks to be used to compare various processes is the separation factor, i.e., the ratio of relative abundance of U-235 before and after the processing of one SWU. For gaseous diffusion, the separation factor is 1.00043; for ultracentrifugation, it is 1.5; for both laser processes mentioned, it is 10. In other words, if you start with natural uranium (0.71% U-235), you obtain after one separative element the following concentrations: 0.7103% for gaseous diffusion, 1.065% for ultracentrifugation, and 7.1% for laser processes. With laser enrichment, it is much easier to obtain the higher U-235 concentrations needed for military use (more than 90%), for feeding the starting period of an ambitious fast breeder reactor program (12 to 15%), and for future liquid-fuel nuclear fission reactors.

Laser separation techniques also valorize natural uranium much better, because they allow a lowering to almost zero of the U-235 content in the waste uranium (about 0.2 to 0.3% with conventional techniques). In other words, laser enrichment processes reduce by 20 to 30% the amount of natural uranium needed. Furthermore, laser processes not only allow separation of U-235 from U-238, but also allow extraction of parasitical uranium isotopes, especially U-236 which does not occur naturally but is created in nuclear reactors, complicating the recycling of the uranium extracted during reprocessing of burnt-up nuclear fuels. This means that it becomes possible to recover the totality of the U-235 (usually about 0.9%) still contained in burnt-up fuels. This makes reprocessing significantly more cost-efficient.

Thus, laser enrichment technologies are more efficient than ultracentrifugation, especially if we intend quick expansion of worldwide nuclear-energy use, including the expansion of advanced reactor designs and processes such as fast breeders, reprocessing, liquid fuel reactors, etc.

It is to be noted that all the modern processes presently in competition require and may stimulate frontier technology developments. Ultracentrifugation needs ultra-resistant materials developed by the aerospace industry; laser processes imply an improvement of existing lasers and a better knowledge of laser-matter interaction; cyclotron resonance is related to plasma physics and may help to shorten the path to thermonuclear fusion. But in the present situation, improvement of laser technologies is certainly what is most urgently required, because of civilian (laser cutting, inertial fusion, telecommunications, etc.) as well as military (beam-weapons) applications.

It is thus to be hoped that the DOE policymakers will not be too prudent and short-sighted in their choice, selecting the "easier" ultracentrifugation technique, but will consider the significance of the spinoffs associated with directed energy techniques.

Panama labor puts

by Carlos Wesley

Within days after Panama's National Council of Organized Workers (Conato) held its second conference on Jan. 10 and 11 on "The IMF and Ibero-America's Debt Crisis," the battle has heated up between Panamanian President Nicolas Ardita Barletta's attempt to impose the International Monetary Fund's austerity program piecemeal and an anti-austerity alliance led by the country's organized labor movement and informed by the program outlined in *EIR*'s cover story of Jan. 7, 1985 ("A winning strategy for the second Panama Canal").

The two-day Conato conference in Panama City concluded with a call for global debt negotiations between the governments of the creditor countries and the debtor nations; suspension of debt repayments until the economic situation of the indebted countries improves; and the building of great development projects, such as a second Panama canal at sea level, capable of handling ships of 300,000 tons. This would industrialize Panama.

More than 200 labor leaders participated in the conference, including delegations of trade unionists from Argentina, Colombia, and Peru. Among the featured speakers were four leaders of the international Schiller Institute, who carried the day against an unholy alliance of Jesuit-tied and Communist Party economists opposed to the debt moratorium and infrastructure-project proposals.

Less than a week later, 150,000 Panamanians went out on Jan. 17 on a 24-hour strike to protest President Barletta's steps toward implementation of the IMF's demands to hand over control of the economy to foreign creditors. Barletta has announced that 20,000 public workers would be laid off, and that three state enterprises would be sold. To sweeten the pill, the U.S. banks have granted a three-month extension in debt repayments and a $30 million outright gift to Panama— an unheard-of concession. The mass protests of late November-early December had forced Barletta to back down from his decision to mandate the full IMF austerity program at that time.

'The IMF made a mistake'

Eduardo Ríos, the leader of Panama's Building Trades and Allied Workers Union and the current coordinator of Conato who chaired the Jan. 10-11 conference, reported that "when Panama's President Nicolas Ardito Barletta, the former vice president of the World Bank for Latin America, proposed an International Monetary Fund austerity package to pay the debt a few months ago, most people didn't even know what the IMF was." Ríos continued: "I knew a little because I had just subscribed to the Spanish version of *Ex-*