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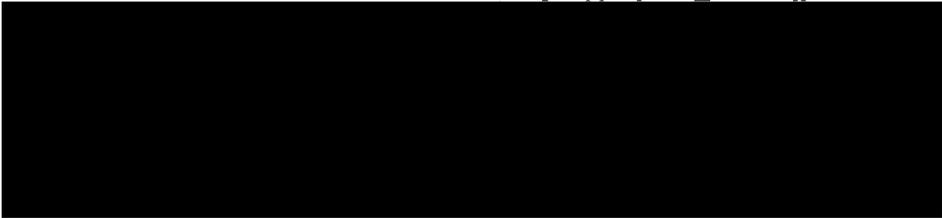
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## SOVIET RESEARCH ON URANIUM LASER ISOTOPE SEPARATION

OSI/CIA

### TECHNICAL FOREWORD

The concept of isotope separation by photoexcitation was considered as early as 1922 by scientists throughout the world; such a separation would attempt to take advantage of the slightly different energy levels that exist in isotopes of the same elements. Mercury isotopes were separated successfully in the laboratory, using ultraviolet light, in 1931. In World War II, when uranium enriched in the  $U^{235}$  isotope became a requirement for the manufacture of nuclear weapons, Harold Urey investigated uranium hexafluoride ( $UF_6$ ) and uranium hexachloride ( $UCl_6$ ) in attempting to find a uranium isotope separation method based on photoreactions. But all such attempts to separate uranium isotopes failed because ordinary light sources could not be tuned to narrow enough bandwidths to allow excitation of one isotope without affecting the other.

The development of the laser revived world interest in photoexcitation as a means of uranium isotope separation in the 1960s. Tunable lasers, emitting nearly monochromatic, coherent light, permitted examination of the spectral characteristics of uranium isotopes and their compounds with greater precision and detail than ever before, revealing spectral regions of potential interest. It remained to develop lasers of sufficient power and stability that also could be tuned to the selected wavelengths, in order to effect a separation.

Two different approaches have been taken in attempting to develop a uranium laser isotope separation (LIS) process: (1) selective photoionization of metallic uranium vapor and (2) photodissociation of uranium hexafluoride gas. Successful laboratory separations have already been announced in the United States using the photoionization method, and a pilot plant is under construction. In this method, atoms of the  $U^{235}$  isotope are ionized selectively by laser action and then can be separated by a magnetic field. A major disadvantage is that the uranium metal must be heated to over  $2000^{\circ}C$  to convert it to the vapor state. At these temperatures the corrosion problems are formidable. Also, the energy requirement is obviously large.

The second method, thought by many to have the greater potential for successful commercial development, involves selective laser excitation of  $UF_6$  gas at low temperatures followed by laser induced dissociation, resulting in the formation of uranium pentafluoride ( $U^{235}F_5$ ), which can be separated by conventional means. This method might also lend itself to a chemical reaction of the excited molecules, again allowing separation from the unexcited  $U^{238}F_6$  by ordinary means.

## CONCLUSIONS

1. The Soviets have a classified program under way to develop an efficient, inexpensive laser isotope separation (LIS) process for the production of enriched uranium.

2. The Soviets could achieve at any time, if they have not already done so, a laboratory demonstration of feasibility for the separation of uranium isotopes by laser photodissociation of uranium hexafluoride (UF<sub>6</sub>) gas. [REDACTED]

[REDACTED] they are strong in laser spectroscopy and laser development; and they are known to have a high interest in uranium isotope separation by this technique. It is unlikely that they have succeeded in demonstrating a working process using this method.

3. [REDACTED] the Soviets probably separated measurable amounts of uranium isotopes in the

laboratory by the selective ionization of hot metallic uranium vapor, a process similar to that described in US publications. [REDACTED]

4. The economic gain for the Soviets from a successful uranium LIS process would derive from increased sales of enrichment services to countries requiring nuclear power reactor fuel, as well as from the ability to extract the U<sup>235</sup> remaining in their stockpile of gaseous diffusion plant tails.

5. The process also could provide the Soviets with a flexible capability to increase production of weapon grade uranium.

## SUMMARY

[REDACTED]

[REDACTED]

[REDACTED]

The motivation behind the Soviet uranium LIS program appears to be primarily economic. A successful uranium LIS process could result in more contracts to supply uranium enrichment services for Western countries that require slightly enriched uranium to fuel nuclear power reactors. Another economic benefit would derive from the ability of the Soviets to use an efficient LIS process to extract the  $U^{235}$  remaining in gaseous diffusion plant tails.

The Soviet need for additional weapon grade uranium really cannot be determined. But a uranium LIS process would permit them to expand future production of nuclear warheads if the decision were made.

## DISCUSSION

### Research on Photodissociation Methods

The Soviets were the first to separate isotopes by a two-step photodissociation method using lasers. V. S. Letokhov and his principle collaborator, R. V. Ambartsumyan, achieved international recognition in 1973 when they published on the separation of nitrogen-14 from nitrogen-15 by photodissociation of ammonia ( $NH_3$ ) molecules by laser excitation.

In the course of their work on photodissociation of isotopes of elements other than uranium, the Soviets

are obtaining data and experience useful to their classified work on uranium LIS. For example, in 1975 they published their work on sulfur hexafluoride ( $SF_6$ ); that work, which resulted in the separation of sulfur isotopes, probably was done because  $SF_6$  is analogous to uranium hexafluoride ( $UF_6$ ).

He was quite interested in US uranium LIS research, particularly with regard to  $UF_6$  spectroscopy and expansion cooling. The Soviet work published on osmium tetroxide ( $OsO_4$ ) is an indication that they were studying the spectra of heavy elements approaching the complexity of uranium, since the separation of  $OsO_4$  is otherwise of academic interest only.

A phenomenon known as "super excitation" was used by the Soviets in the  $SF_6$  LIS work described

above. In this technique, extremely intense laser light from a carbon dioxide (CO<sub>2</sub>) infrared laser is used to excite selectively molecules of a compound such as SF<sub>6</sub> to an energy threshold. Further radiation by the same laser then caused dissociation to occur.

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

**Research on Photocionization Methods**

The Soviets may have separated uranium isotopes experimentally in 1972 or 1973, using the selective excitation and ionization of hot metallic uranium vapor. This process is similar to the process used in the successful demonstrations in the United States at the Livermore and Jersey Nuclear-Avco Laboratories.

If the Soviets did indeed successfully demonstrate uranium isotope separation by the photoionization approach, they may since have abandoned or downgraded their efforts to develop it as a process.

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[REDACTED]

their efforts to be first to develop a uranium LIS process. If the process can be operated as efficiently and inexpensively as its proponents envision, the USSR could make a drastic cut in the price of enrichment services and thus capture a significantly larger share of the world market as the need for power reactor fuel grows. The Soviets have obtained enrichment service contracts with nine Western countries since 1971, totaling nearly 30,000,000 separative work units (SWU), or enough enrichment to produce slightly enriched uranium for about 100 core loadings for typical 1000-MWe pressurized-water reactors (PWRs). The Soviets are extremely interested in expanding this source of revenue.

[REDACTED]

[REDACTED]

**Motivation for Soviet LIS Work**

**Economic forces** [REDACTED]

[REDACTED] appear to be motivating the Soviets in