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This is in further response to your Freedom of Information Act (FOIA) request of April 24, 2012, for a copy of the following report: FSTC 381-4007 - Soviet Basic Research in Stimulated Emission of Nuclear Radiation (1965) and supplements our response of September 6, 2013.

As noted in our letter, coordination has been completed with another government agency and the manual has been returned to this office for our review and direct response to you.

We have completed a mandatory declassification review in accordance with Executive Order (EO) 13526. As a result of this review, it has been determined that the Army information no longer warrants security classification protection and is partially releasable to you. A copy of the manual is enclosed for your use.

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Enclosure

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U. S. ARMY MATERIEL COMMAND

FSTC 381-4007

AST-15005-407-65

SOVIET BASIC RESEARCH IN STIMULATED EMISSION OF NUCLEAR RADIATION (U)

U S ARMY
FOREIGN SCIENCE
AND
TECHNOLOGY
CENTER

October 1965

AN ARMY INTELLIGENCE DOCUMENT

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21 OCT 1970

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DESCRIPTORS

Gamma radiation, graser, Mössbauer effect, stimulated emission, nuclear resonance scattering, superradiance, nuclear physics.

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FSTC 381-4007

SOVIET BASIC RESEARCH IN STIMULATED EMISSION OF NUCLEAR RADIATION (U)

October 1965

(Based on information available as of April 1965)

ABSTRACT

(U) Soviet basic research in the stimulated emission of nuclear radiation is reviewed and analyzed; the foreign literature search was closed in January 1965. A tutorial introduction to the graser concept and alternate approaches to the problem are given, and the present state of the art is summarized from both theoretical and experimental points of view. Fifteen significant papers are discussed, and conclusions are drawn about the present and future Soviet capabilities in basic graser research.

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PREFACE

(U) (C) This study is the result of a requirement from the U.S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, for information on basic and applied work on atomic and nuclear resonance phenomena, with emphasis on applications of the principle of stimulated emission of atomic and nuclear radiation. A separate report will be published on stimulated emission of atomic radiation (laser), so that the present study deals only with the stimulated emission of nuclear radiation (graser).

(U) (C) Attention has been focused on the open Soviet physics literature through January 1965 for source data on grasers. The classification level of this study results from inclusion of an intelligence analysis and interpretation of the existing data, as well as the limited references to classified reports.

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SOVIET BASIC RESEARCH IN STIMULATED EMISSION OF NUCLEAR RADIATION (U)

COMPENDIUM

1. (U) ~~(C)~~ PURPOSE

The purpose of this study is to analyze and evaluate the Soviet literature on nuclear resonance phenomena for estimating present and future Soviet capabilities to perform the needed basic physics research and to develop a graser from applications of the principle of stimulated emission of nuclear radiation.

2. (U) ~~(C)~~ SCOPE

The study covers the stimulated emission of nuclear radiation in the form of gamma rays. The stimulated emission of atomic radiation in the microwave, infrared, and visible wavelengths, popularly referred to as masers or lasers, is not included. The source data for this study were obtained from a search of the Soviet Bloc physics literature through January 1965 and from classified technical intelligence reports of the same period. A cursory search of worldwide physics literature on nuclear resonance phenomena was also made because of its probable influence on Soviet progress in this field.

3. (U) ~~(C)~~ SUMMARY AND CONCLUSIONS

a. (U) The conceptual basis of a graser is developed with the aim of giving the reader the essence of the problem. Equations giving the probability of stimulated emission by using the Mössbauer effect are developed. The sources and effects of pure gamma-ray line broadening are discussed. The potentiality for gamma-ray amplification via the Mössbauer effect is stressed, as are its limitations. Alternate approaches to a graser are mentioned, including the use of microwave frequencies for stimulating forbidden nuclear transitions to emit two photons, and the use of low Z materials for eliminating the loss of on-energy radiation by interaction with atomic electrons. Recent U.S. and Soviet papers on nuclear superradiance are mentioned. The present state-of-the-art is summarized both qualitatively and quantitatively.

b. (U) ~~(C)~~ Two Soviet papers on grasers are analyzed in depth. One is a theoretical study, "The Kinetics of Induced Mössbauer Radiation," by B.V. Chirikov, which undertakes the problem of reflecting gamma radiation to obtain graser action. The other paper, "Resonance Excitation of an Isomer State in Ag^{107m} with a Mean Lifetime of 63 Seconds," by G.E. Bizina and three coauthors is a report on the measurement of the narrowest linewidth to date by means of the Mössbauer effect. The significance of these papers taken separately and together is developed and examined with the results forming the basis for the conclusions (par. 3). Highlights of the Communist World press coverage of Chirikov's paper are mentioned.

c. (U) Thirteen recent scientific papers of direct and peripheral relevance to grasers are abstracted. Five of these papers are non-Soviet and are included because they pertain to the graser problem.

d. (U) Soviet scientists have been working on the graser since 1960. The conclusions below are based on the discussions in paragraphs 8 and 9, beginning on page 14.

e. (U) ~~(C)~~ A coordinated program for study of this problem has conceivably existed among the Nuclear Physics Institute in Novosibirsk, the Institute of Theoretical and Experimental Physics in Moscow, and the Kurchatov Atomic Energy Institute, also in Moscow.

f. (U) ~~(C)~~ Several of the most capable and renowned Soviet physicists have been involved in and consulted on this Soviet work. Among these physicists are L.D. Landau and I. Ya. Pomeranchuk of the U.S.S.R. Academy of Sciences, probably G.I. Budker, director of Novosibirsk Nuclear Physics Institute, and possibly P.L. Kapitsa, director of the Institute of Physics Problems, Moscow.

g. (U) ~~(C)~~ The Soviets seem to be publishing freely in this area, indicating that their evaluation is probably similar to that of U.S. scientists; namely, that realization of a graser is presently problematical and that, if feasible, the practical development would require several years. In the past the Soviets have released data involving potential military application of basic research well after equivalent U.S. work has been declassified. This trend has not been followed in the graser area, where the Soviets appear to be publishing without restriction or delay.

h. (U) ~~(C)~~ Judging by the quality of Soviet efforts in graser research, the reports of which are reviewed in paragraphs 8 and 9, as well as by the high quality of Soviet theoretical studies in solid-state and nuclear physics, the potential of the U.S.S.R. for future progress in the graser area is equal to that of the United States.

DISCUSSION

Section I. (U) BACKGROUND

4. (U) THE GRASER CONCEPT

a. In concept, the gamma-ray amplifier is similar to a laser in many respects; however, the gamma-ray amplifier has important fundamental differences from light amplification because of the much higher frequency of the radiation. These differences have made the realization of a graser problematical.

b. Using the development of Vali and Vali (ref. 1), the following equations describe the physics of a graser. For a crystal containing N excited nuclei, N_f nuclei in the ground state, and N_e atoms, the spontaneous decay of the excited level is

$$\frac{dN}{dt} = -\lambda N \qquad (1)$$

where λ is the (radioactive) decay constant. If stimulated emission also occurs, equation 1 then becomes

$$\frac{dN}{dt} = -\lambda N(1+p) \qquad (2)$$

where p is the probability of a gamma ray stimulating emission. This probability is defined as

$$p = \frac{N\sigma}{N_e \sigma_e} \qquad (3)$$

where σ is the cross section for stimulated emission and σ_e is the electronic cross section for the photoelectric and Compton effects, the primary loss mechanisms. Nuclear resonance absorption has been neglected in the denominator because population inversion, where $N >> N_f$, is assumed. Equivalent definitions of equation 2 refer to p as the number of photons per mode and $\lambda(1+p)$ as the stimulated emission rate. This result was first derived by Einstein and is applicable to both masers and lasers.

c. Unlike atomic transitions (laser and maser), gamma rays impart a measurable recoil to the emitting nucleus, and the resulting spread of gamma-ray energies greatly decreases the probability of stimulated emission because the exact energy of the nuclear transition is needed to trigger (stimulate) emission. Therefore, conditions for recoilless transitions (Mössbauer effect) are assumed to be necessary. This additional restraint modifies the stimulated emission cross section of ofm, where internal conversion of the excited level has been assumed to be zero. If f is the fraction of gamma rays emitted without recoil (Debye-Waller factor), and m is the line broadening as the result of second-order effects, then

$$p = \frac{N\sigma}{N_e\sigma_e} fm \quad (4)$$

The dependence of f on the energy of the transition and on the Debye temperature of the crystal environment limits the nuclear transitions to less than 200 KeV and favors high Debye temperatures. When the crystal is cooled to low temperatures, with fulfillment of the two conditions cited above, f can approach 1. However, the ratio of pure to broadened linewidths, m, is very small because the elimination of second-order effects requires the crystal environment to be controlled several orders of magnitude better than can be achieved at the present.

d. Vali and Vali discuss the second-order effects, each of which will produce a line broadening equal to the natural width. As a favorable instance they take the 40-KeV, 57-minute excited level of Rh^{103} with a natural width of $2x10^{-19}$ eV. A gamma ray falling through 500 Å will be shifted off resonance by the gravitational field; the same broadening will occur if the environment is not uniform in temperature to (10^{-9}) °K. The same effect will occur from minute crystal imperfections that cause electric-field nuclear quadrupole interactions. Finally, the broadening resulting from the magnetic dipole moment interaction between ground states N_f and excited states N is extremely large. In the Soviet experiment on the Ag^{107} isomer, described later, the magnetic interaction produced a broadening equivalent to 10^6 linewidths or $m \sim 10^{-6}$. Although Vali and Vali state that this type of magnetic effect can be averaged out by applying an external radio frequency field, this hypothesis has not been demonstrated in the laboratory on any nuclei of graser interest. Other effects, not mentioned here, can be found in references 1 and 2. The time development of equation 2 is not considered here. Some progress has been made in this area (ref. 3, 4, and 5), but the results and conclusions are divergent.

e. Two other problems hampering the realization of a graser are population inversion of the nuclear levels $N > N_f$ and reflection of the gamma rays to build up a coherent wave. Both of these conditions are necessary in the creation of lasers and masers, but some doubt exists as to the necessity of their fulfillment in the case of grasers (ref. 6).

f. In principle population inversion can be achieved by a Szilard-Chalmers reaction (ref. 7); however, in practice the inverted system would be both extremely radioactive and expensive to make. The problem of finding a suitable reflector for gamma radiation—if needed (ref. 3)—as effective as the mirrors used in lasers seems unusually difficult because of the limits imposed by the physical interaction of gamma radiation with matter. Chirikov has proposed a solution to this problem, which will be discussed later in this report.

5. (U) POSSIBLE APPROACHES TO A GRASER

a. Use of the Mössbauer effect has been assumed to be prerequisite toward realization of a graser. Indeed, practically all of the studies to date have assumed its necessity. Nuclear isomer levels are so narrow that recoilless events will be necessary to stimulate emission. However, at least two other approaches to stimulated emission of gamma rays have been made:

(1) Robl (ref. 8) of the U.S. Army Research Office, Durham, has suggested using microwave frequencies to stimulate forbidden ($0 \rightarrow 0$) nuclear transitions to emit two photons. Such an effect has recently been observed (ref. 9) in atomic transitions with the advent of high intensity lasers, but the spontaneous two-photon de-excitation from a nuclear level has not yet been observed although several attempts have been made (ref. 10).

(2) Schawlow (ref. 11) has suggested using very low Z materials, such as hydrogen or lithium, to minimize the loss of radiation by interaction with the atomic electrons, i.e., to reduce the denominator in equation 3. This hypothesis will necessitate stimulated emission without the Mössbauer effect because the light nuclei would be free to recoil. Even with a large fraction of the radiation being off resonance,

the gain from the reduction in atomic absorption might, according to Schawlow, compensate for the huge reduction of nuclear resonance events.

b. Baldwin et al (ref. 5 and 6) have hypothesized directionality and coherence from spontaneous emission as alternatives to the Mössbauer effect. The effect is termed nuclear superradiance and depends on the occurrence of discrete momentum transfer between the solid-state environment and isomer nuclei. The recent Soviet work of Zaretskiy and Lomonosov (ref. 4), which will be discussed later, is along these same lines of thought, but presupposes the effective use of the Mössbauer effect.

6. (U) PRESENT STATE-OF-THE-ART

a. Gamma-ray amplification by the stimulated emission of radiation has not been demonstrated as a workable device either in the laboratory or from theoretical analyses. Although the scientific community is pessimistic about the near-term realization of a graser, the continued work of Baldwin et al at the General Electric Company and recent Soviet studies indicate that some theoretical interest still exists in this area.

b. To give a quantitative view of the present state-of-the-art, the experimental result of Bizina et al will be combined with equation 4 to arrive at a value of p. In their experiment to measure the Ag^{107} nuclear resonance absorption by exciting its 93-KeV, 63-second isomer, the Soviets found that $m = 2x10^{-6}$ after eliminating several of the second-order broadening effects. They attributed this remaining broadening to magnetic dipole interaction. By assuming all of the nuclei are in the isomer level,

$$p \approx 0.1m$$

for both Ag^{107} or Rh^{103}, which was considered by Vali and Vali (ref. 1), so that

$$p \sim 10^{-7}$$

Even a further idealization of their result (i.e., removing the dipole broadening by the method proposed by Vali and Vali) would conceivably raise the probability to no more than $p \sim 10^{-4}$.

c. These works illustrate that realization of stimulated emission of gamma rays by means of the Mössbauer effect, even with two greatly favoring assumptions, is many orders of magnitude beyond the present experimental state-of-the-art.

Section II. (U) ~~(C)~~ ANALYSIS OF CURRENT STUDIES

7. (U) ~~(C)~~ DISCUSSION OF CHIRIKOV'S PAPER

a. (U) ~~(C)~~ Chirikov's paper (ref. 3), "The Kinetics of Induced Mössbauer Radiation," is of interest to this study for several reasons. A theoretical calculation of the graser problem, this paper refers to three Soviet patent disclosures and an inhouse Novosibirsk Laboratory report. All of this information is on grasers and is not available to the scientific community outside of the Soviet Union. Chirikov also mentioned the "extremely active investigation of the Mössbauer effect presently being performed" 5 months before the experimental study of Bizina et al (ref. 2) on the same subject was submitted for publication. Chirikov's paper has been picked up by the Soviet Bloc popular press as the basis for a gamma-ray amplifier and appeared in the open literature simultaneously with the first open study (ref. 1) of the graser problem by U.S. scientists. These and other reasons for the importance of Chirikov's paper will be expanded in the following discussion.

b. (U) The problem was to obtain gamma-ray amplification by reflecting gamma rays in a direct analogy to the optical cavity of a laser. As a basis for his calculation, Chirikov took a hypothetical crystal containing pure nuclear isomer (100% of the nuclei in a long-lived excited state) with a lifetime of 10,000 seconds. He developed the cross section for stimulated emission by applying the first-order perturbation theory of quantum mechanics to describe the electromagnetic interaction between the radiation field and the nucleus. The result is a cross section that is a function of the developing gamma-ray avalanche. This time-dependence makes Chirikov's calculation significant, because other approaches have treated this problem statically. A kinetic equation having the time-dependent cross section for stimulated emission is solved with reasonable boundary conditions. The important, and perhaps startling, result arises at this point. Although a gamma ray traverses $3x10^{10}$ cm in 1 second, the region of maximum stimulated emission moves with very low velocity and travels 1 mm in the same time. In other words, a crystal several centimeters long is an infinite medium to the developing graser, so that reflection is not necessary. No obvious inconsistencies exist in the derivation although several assumptions were made that require further study.

c. (U) ~~(C)~~ In the "Introduction" to his paper, Chirikov refers to two Soviet patent disclosures issued to L. Rivlin in early 1961 and also to two other studies by Rivlin and one report by Chirikov. All deal with the possibility of producing a graser. Both U.S. and foreign attempts to obtain these patents and reports have been unsuccessful, even though source documents referred to in open literature usually are readily accessible to the scientific community. A report by the Aerospace Technology Division of the Library of Congress (ref. 12), in discussing the Chirikov paper commented that Rivlin had been active in bionics. This report also noted that three patents were granted to him in 1962, one of which dealt with a fiber optical laser for use in high-speed computers. Chirikov's previous publications reveal that he was active in electron beam physics and controlled thermonuclear reaction (CTR), and that he worked for G.I. Budker, the dynamic leader of the Novosibirsk Nuclear Physics Institute. This Institute is gaining international recognition because of the high quality and unconventional nature of its research, especially in the area of storage rings for high-energy particles. Chirikov appears to be presently active in this latter area.

d. (U) ~~(C)~~ In regard to the possible relationship between his theoretical calculation and the experimental work and observations of the Mössbauer effect in Ag^{107m} by the Moscow group, Chirikov stated in his paper that

> The main problem in the way of solving this first problem (observation of weak amplification of a gamma wave) is to find an extremely narrow Mössbauer line. This difficulty may well be overcome, in view of the extremely active investigation of the Mössbauer effect now going on.

Chirikov is possibly referring to the Bizina experiment, inasmuch as 5 months separate the publication of the results of the two studies and, more significantly, since the observed line from the 63-second isomer of Ag^{107} is the narrowest absorption line reported to date.

e. (U) The Soviet Bloc press and popular science media have been publishing articles on Chirikov's paper since December 1963. Some of their comments are: "Soviet Scientists of the Siberian Institute of Nuclear Physics have developed the basis for a new type of maser . . . suitable for work in the gamma range." (ref. 13) and that

> In this maser, far reaching military potential is possible, though there are also many peaceful uses. By means of this gamma maser one can produce underwater, as well as underground, communications . . . radiation chemistry in which intensive gamma radiation could develop new reactions . . . graser has also a great future in nuclear physics (ref. 14).

Other sources note that "Under these conditions the laser produces a coherent gamma beam with an extremely high intensity. Such a beam would kill a human being instantly" (ref. 15). Finally, a news item stated that Soviet scientists B. V. Chirikov and L. A. Rivlin were working on a gamma laser (ref. 16).

f. (U) ~~(C)~~ The final noteworthy aspect of the Chirikov paper is the timing of its publication in Soviet open scientific literature. The paper was submitted for publication on 7 January 1963, and was published in June 1963. A U.S. paper, "Induced Gamma-Ray Emission" by W. Vali and V. Vali, appeared in January 1963 (ref. 1) and was presented at the Third International Symposium on Quantum Electronics in Paris in February 1963. Soviet authorities usually very carefully control the release of scientific studies concerning potential military applications well after comparable U.S. or Western studies have been published. Of significance, then, is the fact that Chirikov's papers appeared on the heels of the first U.S. open publication and, more importantly, that it not only extended knowledge of the graser potential in a non-trivial manner, but also disclosed that the Soviets have studied this problem since at least late 1960.

8. (U) ~~(C)~~ DISCUSSION OF BIZINA'S PAPER

a. (U) ~~(C)~~ The experimental study by Soviet physicists G. E. Bizina, A.G. Beda, N.A. Burgov, and A.V. Davydov on the first observation of a Mössbauer-type effect from a long-lived nuclear isomer was conducted at the Institute of Theoretical and Experimental Physics in Moscow. This study had the acknowledged support of two leading Soviet physicists of the U.S.S.R. Academy of Sciences, L.D. Landau and I. Ya. Pomeranchuk, and staff members of the Kurchatov Atomic Energy Institute, the Institute of Physics Problems, and the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements. The best facilities and scientists in Moscow were available and participated in this experiment. One obvious reason for the large participation of talent and advanced apparatus is the small-order resonance absorption effect that was anticipated and the attendant interest in Mössbauer effect research. Another reason pertinent to this study, though not so obvious, was the investigation of a potential graser material. This experiment was first suggested by the French (ref. 17) in 1960 and by Burgov and Davydov in an internal report (ref. 18). Apparently scientists working on the Mössbauer effect have been aware of the Soviet effort for some time. Results of the experiment (ref. 19) were presented by Burgov at the Third International Conference on the Mössbauer effect held at Cornell University in September 1963 under the sponsorship of the Advanced Research Projects Agency. In 1960 a French attempt to observe the effect was unsuccessful (ref. 20).

b. (U) In the usual Mössbauer effect study, gamma rays transmitted through a thin foil containing the same nuclear species as the source of the radiation are studied as a function of the Doppler shift between emitters and absorbers. When the sources of displacement of the energy lines of absorption and emission are removed, maximum attenuation of the gamma-ray beam occurs, and this dip in the transmission curve is called the Mössbauer effect. Before the Soviet experiment, the narrowest Mössbauer line occurred in Zn^{67}, a 93 KeV transition with natural linewidth of about 7×10^{-11} eV, or a corresponding lifetime of 10^{-5} seconds.

c. (U) To observe a line much narrower than that of Zn^{67}, Bizina et al recognized that a transmission experiment would not be sensitive enough to detect the effect and that painstaking precautions would be necessary to produce the resonance conditions between the emitting and absorbing nuclei. They eliminated this problem by sandwiching two silver foils together and placing them in a liquid helium cryostat with a carefully controlled acoustic environment; initially one foil contained radioactive Ag^{107m} nuclei, and the second foil was nonradioactive silver such as occurs in nature. After a short period the cryostat was rapidly opened, and the second foil was transferred to a gamma detector. The observed radiation characteristic of the Ag^{107} isomer with an energy of 93 KeV and a lifetime of 63 seconds indicated that resonance absorption had occurred. When the experiment was repeated at room temperature, no induced radiation was detected, substantiating the Soviet claim that the observed phenomenon was the Mössbauer effect. However, the effect was so weak that the observed width of the gamma-ray line was 8×10^{-12} eV, or 8×10^{5} larger than the natural linewidth—with only a factor of 10 improvement over Zn^{67}. This broadening of the natural line was explained theoretically as a result of the interaction between the magnetic dipoles of the excited (isomer) and ground states of Ag^{107}. The broadening also decreases the resonance absorption effect by about 10^{6} times.

d. (U) ~~(C)~~ The preceding technical details are necessary for a good understanding of the impact the Soviet results will have on future graser research. The observed effect of resonance absorption was 10^{6} times smaller than the theoretical maximum, and apparently the cause (magnetic dipole interaction) could not be experimentally eliminated without introducing other sources of broadening (ref. 1) for most of the nuclear isomers of interest as potential graser materials. To be more emphatic, Bizina's result raises very serious questions concerning the success of any graser research through this Mössbauer effect approach, as was also concluded by Ruby (ref. 20). Perhaps for this reason the Soviets were willing to publish this experimental result (which in its own right is respectable and interesting basic research) even though it identifies one blind alley of graser research for U.S. scientists as well.

e. (U) Based on the successful observation of resonance absorption in Ag^{107}, a French scientist (ref. 21) at the Third International Conference on Mössbauer Effect suggested the same approach be taken with the 40-KeV isomer of Rh^{103} with a lifetime of 54 minutes where an effect should be larger. U.S. scientists (ref. 1) had suggested this nucleus earlier, but apparently successful Mössbauer effect experiments have not yet been performed.

9. (U) RELATED PAPERS

Thirteen recent papers of direct and peripheral interest to grasers are summarized. Papers a.-i. are directly pertinent.

a. "Spontaneous Emission of Gamma Quanta from Crystals": D.F. Zaretskiy and V.V. Lomonosov, Kurchatov Institute of Atomic Physics. Zhurnal Ėksperimental'noy i Teoreticheskoy Fiziki (Journal of Experimental and Theoretical Physics), vol. 48, 1965, p. 368. (This paper appears in Soviet Physics-JETP, probably in the June 1965 issue or the July issue.)

The authors consider the possibility of creating graser action through the Mössbauer effect in a perfect crystal. They present a detailed theoretical calculation of the gamma-ray amplification by studying the dynamics of the interaction with the crystal lattice in analogy to the same problem with X-ray diffraction. For an arbitrary number of excited nuclei in the crystal, the authors find that the growth of nuclear excitations is connected with an increasing linewidth of the emitting level and a concentration of the radiation into a narrow solid angle in the direction of the inverse lattice constant. Mention is made of suitably adjusting the lattice parameters by imposing external pressure or temperature.

b. "Nuclear Polarizability, Dispersion, and Reflection Coefficient Near the Mössbauer Line": V.V. Khizhnyakov. Fizika Tverdogo Tela (Soviet Physics-Solid State), vol. 6, 1964, p. 501.

The author considers the theoretical possibilities of nuclear polarizability near a Mössbauer line and computes that a large effect is possible for very soft gamma rays (< 1 KeV). The consequence of this polarization is a large coefficient of reflection from the absorbing medium, which suggests two very important possibilities. First, the reflected radiation, rather than the transmitted, can be observed for increasing the sensitivity of the Mössbauer effect. Second, the absorbing foil can be used as a reflector (mirror) for the Mössbauer radiation; 95% reflection would be obtained for the 70-eV gamma ray from the 26.5-minute isomer of U^{235}.

c. "Resonance Reflection of Gamma Rays from a Crystal Surface": M.I. Podgoretskiy; Joint Institute for Nuclear Research, Dubna.

Zhurnal Eksperimental'noy i Teoreticheskoy (Soviet Physics-JETP), vol. 18, 1964, p. 536.

One of the critical graser problems, the reflection of gamma rays from a crystal as a function of time, is studied. In the calculation, the index of refraction of the reflecting medium is assumed to differ greatly from unity, and large grazing angles for the incident radiation are assumed. For more information, the following portion of Podgoretskiy's abstract is given.

> The time dependence of the intensity of resonance gamma rays reflected from a crystal surface is investigated. It is shown that, when the resonance frequencies of the radiator and reflector are different, the intensity of the reflected gamma rays exhibits "beats". The interference between resonant nuclear scattering and Rayleigh scattering by the atomic electrons is treated. The interference disappears when the resonance frequencies of the emitter and reflector coincide.

In a paper described below, Black et al observed the interference between resonant nuclear and Rayleigh scattering.

d. "Interference between Rayleigh and Nuclear Resonant Scattering in Single Crystals": P. J. Black, G. Longworth, and D. A. O'Conner; University of Birmingham, United Kingdom. Proceedings of the Physical Society (London), vol. 83, 1964, p. 925.

e. "A Measurement of the Debye-Waller Factor for Elastic Nuclear Resonant Scattering of ^{57}Fe Gamma Rays, P. J. Black, G. Longworth, and D. A. O'Conner; University of Birmingham, United Kingdom. Proceedings of the Physical Society (London), vol. 83, 1964, p. 937.

f. "The Theory of the Nuclear Resonant and Electronic Scattering of Resonant Radiation by Crystals": D. A. O'Conner and P. J. Black; University of Birmingham, United Kingdom. Proceedings of the Physical Society (London), vol. 83, 1964, p. 941.

g. "A Direct Observation of Diffraction in Nuclear Resonant Scattering": P. J. Black and I. P. Duerdoth; University of Birmingham, United Kingdom. Proceedings of the Physical Society (London), vol. 84, 1964, p. 169.

These four papers present excellent experimental data and theory on the processes competing with nuclear resonant absorption, a topic of direct concern to graser research. Using the Mössbauer effect as a sensitive detector, the authors investigate and unravel the four components of resonance radiation scattered by a crystal containing resonant nuclei; these components are coherent elastic, coherent inelastic, incoherent elastic and incoherent inelastic scattering. The competing effects are unraveled by observations at the Bragg angle of the scatterers, which are either single crystals or polycrystals, depending on the effect to be investigated.

h. "Suppression of Inelastic Channels in Resonance Nuclear Scattering in Crystals": A. M. Afanasyev and Yu. Kagan. Zhurnal Eksperimental'noy i Teoreticheskoy Fiziki (Journal of Experimental and Theoretical Physics), vol. 48, 1965, p. 327. (This paper appears in Soviet Physics-JETP, probably in the June 1965 issue or the July issue).

The authors theoretically study resonance scattering of particles on perfect crystal nuclei with a low-lying excited state. When the Bragg condition is satisfied, they find the crystal to be completely transparent to the particles. The effect of lattice phonons on the transparency is also analyzed. The application of the authors' results to the Mössbauer effect is considered by taking the problem of resonance scattering of gamma rays. The response of the medium is found to be sensitive to the multipolarity of the Mossbauer transition.

i. "Width and Shift of Coherent Spontaneous Radiation Line of System of Identical Emitters": C. Muzikar, Charles University, Prague. Chekhoslovatskii Fizicheskii Zhurnal (Czechoslovak Journal of Physics), vol. 14, 1964, p. 211.

The influence of the retarded electromagnetic interaction of a system of oscillators in a cubic lattice on the form of the spontaneous radiation line is studied. The broadening of the line is calculated for wavelengths, both longer and shorter than the lattice constant, specifically for gamma, optical, and microwave radiation. The general method that the author developed in a previous paper is based on complete retarded interaction and on integration in reciprocal space. As a result of his method, coherent radiation in the three regions mentioned can be studied. The results obtained are approximately valid for noncubic crystals, and the method can be used to study emitters arranged in a plane lattice or linear chain.

j. "Optical Analogue of the Mössbauer Effect": E. F. Gross, S. A. Permogorov, and B. S. Razbirin; A. F. Ioffe Physical-Technical Institute. Doklady Akademiya Nauk SSSR (Soviet Physics-Doklady, vol. 9, 1964, p. 164).

Observations of very sharp, and extremely temperature-dependent, emission and absorption lines in atomic spectra are reported by the authors. In 1958 R. Mössbauer discovered that recoilless transitions could occur in nuclear spectra. In the present research emission and absorption spectra of crystals such as CdS, CdSe, and ZnS were studied in the optical region. At 4^{0} K, sharp lines 0.2 Å wide at 4800 Å were superimposed on the usual broad (10Å-wide) absorption lines. The sharp spikes rapidly disappear with increasing temperature, indicating that the new effect has a temperature dependence similar to the Mössbauer effect; the authors suggest that this effect may be an optical analogue to the Mössbauer effect. If their interpretation is borne out, the impact on research in physics and chemistry could be as great as that made by the original Mössbauer effect.

k. "Double Reflections of X-Rays in Crystals: Yu. S. Terminasov and L. V. Tuzov. Uspekhi Fizicheskikh Nauk (Soviet Physics-Uspekhi, vol. 83, 1964, p. 223).

This lengthy article on double reflections of X-rays from crystals reviews the literature on the subject through 1963. Rather than a direct application for X-ray amplification, the possible areas of application of double reflection in crystal structure studies are discussed.

l. "Theory of Resonant Electromagnetic Systems with Total Internal Reflection. II": L. V. Iogansen. Zhurnal Tekhnicheskoi Fiziki (Soviet Physics-Technical Physics, vol. 8, 1964, p. 985).

The theoretical basis for a new device that enables electromagnetic waves to be focused, stored, and filtered is discussed. This device is a resonant condenser based on what the author calls the resonance fringe (edge) effect in plane-stratified dielectric systems with totally reflecting interlayers. This resonance diffraction by plane-stratified layers is shown to apply to plane waves of any nature as well as to electromagnetic waves. Detailed calculations are made for s- and p-polarized waves.

m. "On Resonance-Induced Scattering and Radiation in a Medium": V. N. Tsytovich; P. N. Lebedev Institute of Physics, Moscow. Doklady Akademiya Nauk SSSR (Soviet Physics-Doklady, vol. 9, 1964, p. 49).

This paper is a theoretical calculation describing nonlinear effects of two photon processes in the presence of Cherenkov radiation. Because the latter radiation originates from high-velocity charged particles in a medium, the calculation is more relevant to plasma physics than to areas associated with graser research.

APPENDIX (U)

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