STUDIES OF NUCLEAR RESONANT ABSORPTION OF GAMMA RAYS

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U. S. Atomic Energy Commission
Argonne, Illinois

Contract No. AT(11-1)-578
Project Agreement No. 6

"AEC Research and Development Report"

25 years of research
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of
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ARF 1166-18

STUDIES OF NUCLEAR RESONANT
ABSORPTION OF GAMMA RAYS

to

U. S. Atomic Energy Commission
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois

Attn: Fred C. Mattmueller, Director
Contracts Division

(Covering the Period from September 1 to November 30)

March 7, 1962

ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY
I. INTRODUCTION

This report describes the work performed under contract No. AT(11-1)-578, entitled "Studies of Nuclear Resonant Absorption of Gamma Rays," during the period from September 1, to November 30, 1961. The level of effort was curtailed on this program during the greater part of this quarter to allow key personnel to work on a program vital to our national defense effort. The requirements of this program were such that a high level of effort over a two month period was required. As a result of this, a time extension of the nuclear resonant absorption program was requested and granted. However, during the initial part of this quarter experiments were carried out to determine whether there was any change in the fraction of recoil free emissions of gamma rays from Fe$^{57}$ due to an increase in pressure at the emitter. Absorption measurements were made using pressures up to 40,000 psi, but no measurable changes were found over this range. During the last few weeks of this quarter, experimental apparatus was assembled in an attempt to measure the acoustical power of transducers in the megacycle frequency range using nuclear resonance absorption techniques. Equipment difficulties prohibited initial measurements at this time, but the troubles are being corrected and initial feasibility measurements will be carried out in subsequent months.

II. EFFECTS OF PRESSURE ON THE FRACTION OF RECOIL FREE GAMMA EMISSIONS

Because the fraction of recoil free gamma emissions depends upon the probability of transfer of momentum to the host lattice as a whole, one would expect an increase of this fraction as the lattice becomes more rigid under pressure. To measure this effect, a pressure bomb was constructed.
in which the Fe$^{57}$ source can be subjected to 40,000 psi. The pressure bomb was fitted with a window assembly consisting of a 0.675 inch diameter beryllium disk 0.100 inch thick, and a $\frac{3}{8}$ inch thick harden steel supporting collimator. The surfaces of the beryllium window and steel collimator were lapped to within one half wavelength and polished to a one micro-inch rms finish so that they would be optically flat for sealing purposes. The beryllium window attenuated approximately 12 per cent of the 14.4 Kev Fe$^{57}$ gamma rays. The steel supporting collimator consisted of twenty-one holes, .020 inch in diameter, symmetrical drilled over a $\frac{1}{4}$ inch diameter area. (See Quarterly No. 3, ARF 1166-9, for photographs of the pressure bomb and window assembly.)

The source used for the pressure experiment was a 2 mc Co$^{57}$ source plated and $\frac{1}{4}$ inch diameter No.316 stainless steel foil 3 mils thick. The resonant absorber foil was a 1 mil thick No. 316 stainless steel foil. A 45 per cent resonant absorption was achieved with this emitter-absorber combination and with the source in the pressure unit.

The detection and counting system, (Fig. 1), consisted of a flow type proportional counter whose output was fed into a multichannel pulse height analyzer. The background with no sources present was approximately 200 counts per hour per channel in the energy region of interest.

In Table I the results of the pressure experiments are shown. Each run consisted of alternately measuring the transmission, for 15 minute intervals, at two fixed pressure. This procedure was followed to compensate for any changes in background and drifts in the electronic equipment with time. With the intensities observed, a 2 per cent change in the transmission intensity could be detected. Because the changes in transmission intensities,
Fig. 1 BLOCK DIAGRAM OF PRESSURE EXPERIMENT APPARATUS
<table>
<thead>
<tr>
<th>Run</th>
<th>Pressure at emitter (psi)</th>
<th>Time of run (min.)</th>
<th>Total counts (Transmission)</th>
<th>Estimated Background</th>
<th>Difference in Transmission Intensities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3,000 ± 500</td>
<td>240</td>
<td>31,934</td>
<td>19,875</td>
<td>249 ± 252</td>
</tr>
<tr>
<td>A'</td>
<td>10,000 ± 500</td>
<td>240</td>
<td>31,685</td>
<td>19,875</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>3,000 ± 500</td>
<td>180</td>
<td>23,225</td>
<td>15,000</td>
<td>437 ± 215</td>
</tr>
<tr>
<td>B'</td>
<td>20,000 ± 500</td>
<td>180</td>
<td>22,788</td>
<td>15,000</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>3,000 ± 500</td>
<td>180</td>
<td>21,852</td>
<td>13,500</td>
<td>288 ± 208</td>
</tr>
<tr>
<td>C'</td>
<td>3,000 ± 500</td>
<td>180</td>
<td>21,570</td>
<td>13,500</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>3,000 ± 500</td>
<td>180</td>
<td>20,080</td>
<td>12,000</td>
<td>-104 ± 201</td>
</tr>
<tr>
<td>D'</td>
<td>40,000 ± 500</td>
<td>180</td>
<td>20,194</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>3,000 ± 500</td>
<td>180</td>
<td>20,810</td>
<td>12,000</td>
<td>-91 ± 204</td>
</tr>
<tr>
<td>E'</td>
<td>1 atm.</td>
<td>180</td>
<td>20,719</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3,000 ± 500 (off resonance)</td>
<td>120</td>
<td>18,518</td>
<td>8,500</td>
<td>4539 ± 180 (≈ 45%)</td>
</tr>
<tr>
<td>F'</td>
<td>3,000 ± 500 (on resonance)</td>
<td>120</td>
<td>13,979</td>
<td>8,500</td>
<td></td>
</tr>
</tbody>
</table>
after correction for background were constant within the statistical error in all cases but one, it can be concluded that any changes in the fraction of resonant absorption due to ambient pressures up to 40,000 psi were less than three per cent.

III. ACOUSTICAL ENERGY DENSITY MEASUREMENTS

The difficulties of measuring acoustical power in the ultra high frequency range by conventional methods have led us to undertake a feasibility study of utilizing nuclear resonant absorption techniques for these measurements. Because the acoustical power is a function of the acoustical frequency amplitude, it is expected that the transmission, through an absorbing foil, of resonant gamma rays emitted from an acoustically modulated source will be a function of the acoustical power. If a Mossbauer source is mounted on an acoustical transducer, the amount of nuclear resonant absorption of the emitted gamma rays will be proportional to the fraction of time the source is not sufficiently Doppler shifted to completely destroy resonance. If the transducer velocity is a sine wave function, the transmission intensity of the resonant gamma rays will be a function of the maximum transducer velocity or amplitude.

Experimental apparatus is currently being assembled for initial measurements of acoustical power in the megacycle frequency range. Several quartz crystals are being prepared for use as acoustical transducers in the 10 to 20 megacycle frequency range. These crystals are \( \frac{1}{2} \)" in diameter and vary in thickness depending on the resonant frequency desired. A suitable transducer mounting assembly is also being constructed. Our Co\(^{57}\)-stainless steel source will be mounted on the transducers, and the transmission through a stainless steel absorbing foil will be detected by a...
flow type proportional counter.

IV. FUTURE WORK

During the time allotted by the extension of this program, we will continue the feasibility study of the acoustical power measurements, refine the magnetic fields on the fraction of recoil free gamma ray emission, and investigate any other practical applications of nuclear resonant absorption phenomena brought to our attention if time allows.

V. PERSONNEL AND LOGBOOKS

The following personnel have contributed to the work described in this report: J. J. Ezop, I. Filosofo, and C. A. Stone. Data pertaining to this program can be found in ARF logbooks logbooks C 10519, C 11411, and C.11618.

Respectfully submitted,

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