HIGH POWER SUBMILLIMETER AND INFRARED RADIATION FROM INTENSE RE-EET
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AFOSR-TR-80-0545
"High Power Submillimeter and Infrared Radiation from Intense Relativistic Electron Beams"

Research Conducted Under: Contract F44620-75-C-0055

Period Covered: 1 January 1975 - 31 December 1979

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A. D. BLOSE
Technical Information Officer
I. Introduction:

The submission of this report marks the end of the first phase of research conducted by the Principal Investigators* on "High Power Submillimeter and Far Infrared Radiation from Intense Relativistic Electron Beams" carried out during the 5-year period 1975-1979 under Contract F 44620-75-C-0055. Phase Two of this research, continuing under grant AFOSR 80-0118, will be directed toward a detailed study of the collective free electron laser developed by this group, with the experimental program utilizing the new up-graded accelerator purchased with special supplementary funds as supplied by the Air Force under the F44620-75-C-0055 contract. (The Physics International Pulserad 220 unit (1 MeV, 20 KA, 100+ nsec) has been installed and is currently undergoing initial testing.)

Part II of this report covers the period 1 Jan. 1979 - 31 Dec. 1979 and is presented for the sake of completeness in the same format as the previous Interim Reports submitted after each of the first 4 years of this contract. Part III is a concise statement of accomplishment in the form of a Bibliographical Summary, detailing in roughly chronological order all papers published during the 5-year contract period.

* Included also is a summary of theoretical studies conducted by Professor S. Johnston (Section II-5-2).

A. Experimental Research

Experimental work this past year, continued on our old Pulserad until Nov. 1979, was oriented towards laying the groundwork for the new Pulserad 220 facility mentioned in Part I. Funds for the latter were awarded in Spring 1979, and the machine was completed and tested within specifications in San Leandro in December, 1979.

A series of experiments was performed to test the dependence of superadiant power generated by stimulated Raman backscattering (at $\lambda_s \approx 2 \text{ mm}$) upon ripple-field amplitude and length. We can now pulse our "undulators" (or "wigglers") to kilogauss amplitude at ripple period of $l=8 \text{ mm}$. However, power emitted from the shell-beam saturated before this point. In anticipation of future experiments which may call for a low total beam current of high density, we also tried a configuration of a pencil beam (dia. $\approx 3 \text{ mm}$) in a $1 \text{ cm}$ drift tube. The rippled period was $l=17 \text{ mm}$, provided by a pulsed bifilar helical winding. Here, a ripple field of up to 2 kG could be obtained; also, we could observe "magnetoresonance", a condition for which the effective pump frequency ($2\pi V_n/e$) was about equal to the electron gyrofrequency ($eB_z/mc$). At that condition, the superadiant power ($\lambda_s \approx 4 \text{ mm}$) decreased, either because of beam scape-off on the drift tube wall or because of beam heating. The experiments did, however, show the feasibility of pencil-beam experiments in our new facility, where $\lambda_s \approx l$ is to be expected.

Experiments were also done using a distributed feedback element in the system (see diag.). The latter is a grooved coaxial element which in theory would a) replace the mirrors in a laser cavity and b) lock the cavity radiation to the mode $\lambda_s = l_0/2$ where $l_0$ is the groove spacing. The grooves were square-channeled corrugations, $\lambda_s/4$ deep. Some evidence
of lasing was obtained (note the pulse length of our Pulserod 105 system is 10 nsec, so lasing is out of the question in a system \( \sim 1 \) m in length), but it was not reproducible. One reason for this trouble is that the tolerance on the groove is very strict: there must be less than \( \lambda_s/2 \) accumulated of random machining error over a grating length of \( \%600 \) grooves to avoid destructive interference. It was decided to postpone further experiments until sometime after the installation of our new facility.

B. Theoretical Research

1. A study was conducted of the growth of circular waveguide modes by parametric coupling to cold beam waves, with field gradient effects included. A revision of a previously submitted paper on this work is in progress. Studies ancillary to some of the experimental work included an exact analysis of the fields of a bifilar helix, including all harmonics and the associated electron orbits. This showed that the electrons may strike the drift tube wall for certain applied fields, which should explain the observed drop-off in superadiant power output as the ripple field is increased. As an aid to distributed feedback experiments, exact expressions for the fields in a corrugated waveguide were derived. A major effort has been directed at means for improving the quality of the beam. Exact equilibria of a perfectly cold beam in Brillouin flow have been examined, for both pencil-beam and annular geometry, with the integral impedance of the driving circuitry included. The purpose is to arrive at a design for launching a cold beam. One scheme under investigation is the matching of the calculated beam impedance to that of the driver. Another is to shape the cathode geometry to conform to the analytically derived electron orbits in the cold equilibrium. This work is continuing.

2. Investigation of a new operating mode has continued for low-
gain recycled systems (viz., the finite length plasma-modified Compton effect). Explicit cold-beam results (including a guide magnetic field) show appreciable gain from spatial transients in an intense beam, and suggest that operation in this mode may avoid the rather stringent limitation on wavelength imposed by beam energy spread for exponential-gain operation. A paper summarizing the results of this study is almost complete.

C. Publications and Talks

1. Published

2. To Appear
3. Technical Talks

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<td>&quot;Distributed Feedback Free Electron Laser&quot;</td>
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<td>f) Schlesinger</td>
<td>&quot;Submillimeter Collective Free Electron Laser&quot;</td>
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<td>g) Marshall, McDermott</td>
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D. Patents

AF Invention No. 13,


(Filed U.S. Patent Office, Nov. 1979).
III. Bibliographical Summary: 1975 - 1979


A series of experiments was performed to test the dependence of superadiant power generated by stimulated Raman backscattering (at 2 mm wavelength) upon ripple-field amplitude and length. Experiments were also performed to understand the possibility of using distributed feedback in a collective mode free electron laser. A theoretical study was completed to understand the growth of circular waveguide modes by parametric coupling to cold beam waves, with field gradients included. This is similar to free electron laser configurations to be studied in upcoming experiments.