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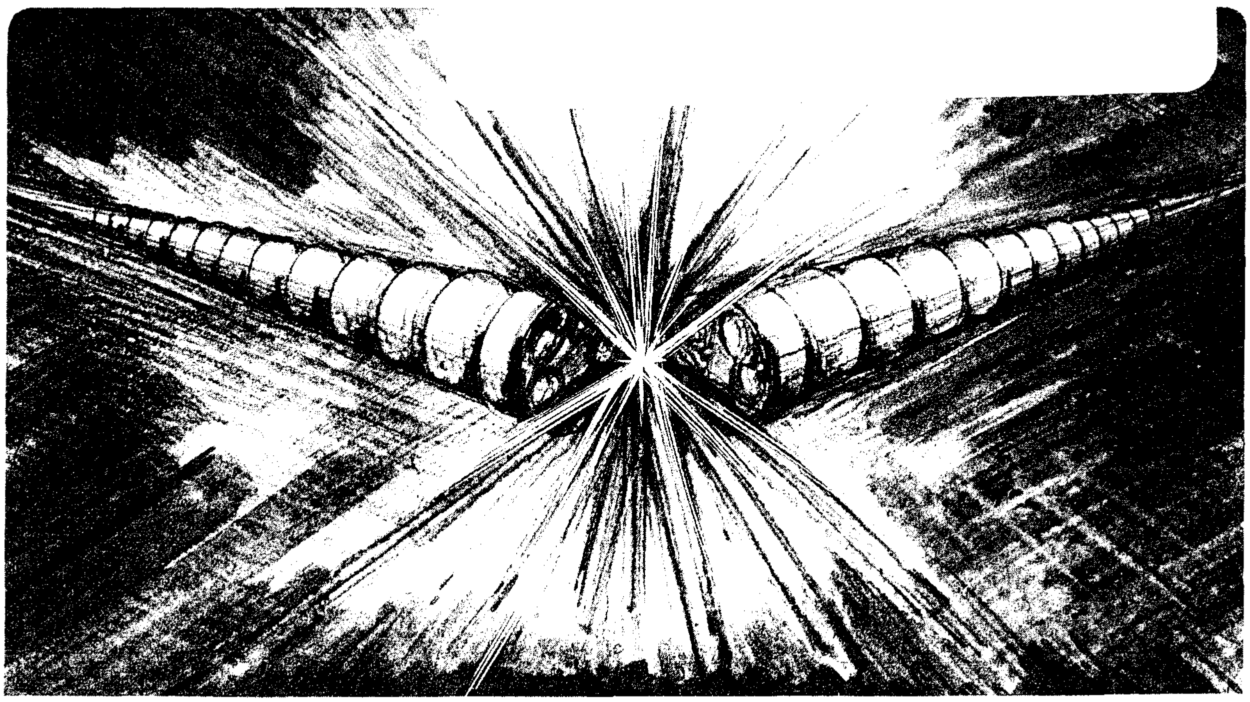

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FREE ELECTRON LASERS FOR THE PRODUCTION OF INFRARED AND MILLIMETER WAVES*

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This paper will present a review of free electron laser (FEL) generation of electromagnetic radiation in the range from 0.5 μm to 10 mm. Most FELs have, infact, operated in this range and employed techniques which can not -- readily at least -- be extended into the ultraviolet and beyond.

The first FEL (1977) by J. Madey et al.,[1] operated in an amplifier (A) mode at 10.6 μm and in an oscillator mode (O) at 3.4 μm where it produced a peak intracavity power of 500 kW. This work was rapidly followed (1977) by that of T. Marshall et al.,[2] who operated an FEL in an amplified spontaneous emission mode (ASE) and generated 8 MW of radiation at 1.5 mm.

Since then many FELs have been operated in A, O, or ASE modes from 1.57 μm[3] to 8.6 mm[4] and with power output ranging as high as more than 1 GW. These FELs include that at the NRL (400 μm)[5], at LANL (10.6 μm)[6], at the NRL (10 mm)[7] and (3.1 mm - 4.6 mm)[8], at MSNW (10.6 μm)[9], at TRW (1.57 μm)[3], at UCSB (400 μm)[10], at LLNL (8.6 mm)[4], at Hughes (10 mm)[11], at Stanford (2.6 μm-3.1 μm)[12], and at Frascati (15 μm)[13].

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Many important things have been learned from these experiments and from the parallel advance of theoretical understanding, the latter of which is based upon many hundreds of papers as well as the experiments themselves. I think it is no exageration to say that our understanding of FELs has advanced to the stage where FELs can be designed to specification and when constructed will operate as predicted.

Infact, quite a lot of projects are now underway, and in the future years we can expect to see many FELs. Some of these projects have enjoyed considerable effort and support, such as those at Glassgow and at Bell Labs; while others have had modest support, such as those at Osaka (which has lased) and at MIT; while others are only in the planning stage such as those at LBL and at Strasbourg.

There is considerable effort being put, especially in the United States, into the development of very high power FELs (at about 1 μm); programs are in place at LANL, LLNL, and Boeing-Spectra Technology. There is some effort being put into the development of compact FELs (at about 1 mm) at NRL and MIT, and there is, also, effort being put into the development of reliable FEL for medical use (in the 2 μm - 10 μm range).

Current theoretical effort ranges widely and most especially includes study of the coherence properties of ASE[14] and sideband (or trapped-particle) instabilities.[15] An understanding of, and special designing of FELs for particular kinds of, optical pulses is an important subject; in particular, it is necessary for many applications to control the sideband growth. Methods for doing this, such as adjusting desynchronism, employing wavelength selective Qs, and properly choosing the electromagnetic pulse group velocity have been proposed and, even, demonstrated experimentally.

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