Observation of Intense Far Infrared Picosecond Pulses of Coherent Transition Radiation

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Transition radiation is produced by the passage of a charged particle through the interface between media with different dielectric constants.[1] It is caused by a collective response of the matter surrounding the particle trajectory to readjust to the electromagnetic field of the charged particle. Part (a) of the figure is a schematic corresponding to the geometry used in our experiment. A negatively charged particle is incident at 45° with respect to a metallic mirror. In the low-frequency region where the metal acts like a perfect conductor, its electric shielding effects can be represented in the nonrelativistic limit by an image charge placed at an equal distance behind the metal surface. As the charge approaches the boundary, so does this image charge. The emitted radiation pattern with a frequency spectrum extending from the microwave to the x-ray region [see (b)] is emitted when the charged particle enters the metal and the charge and its image cancel.

Our experiments have shown that the analysis must be modified if, instead, a charged particle bunch is incident on the conductor. If the bunch length is larger than the wavelength of the radiation, each charged particle in the bunch radiates independently and the intensity is proportional to the number of particles [*e.g.*, (b) at 10^4 cm^{-1}]; however, if the converse is true (*e.g.*, at 10 cm^{-1}), the bunch radiates coherently. Our experiments, which make use of the millimeter long electron bunches from the Cornell linear accelerator, show that in the far IR the radiation intensity is proportional to the square of the number of electrons in the bunch.[2] The total energy per bunch in the far IR is found to be 1.7 μJ for 5×10^9 electrons. This value should be compared with that calculated for a 1 mm Gaussian electron beam incident on a perfect conductor, namely 15 μJ for frequencies greater than 1 cm^{-1}. Coherence effects determine the spectral distribution of the far IR, as illustrated by the experimental data (solid dots) in Part (b). A complete measurement of this spectrum can be used to determine the form factor of the bunch with a resolving power of about 100, since its shape is proportional to the modulus squared of the Fourier transform of the longitudinal electron distribution. In addition, since the output has a peak power of megawatts for picosecond pulse lengths, it can be used for time-resolved pump-probe experiments of solids, liquids, high-pressure gases, and plasmas in the spectral region where low-lying many-body collective excitations are important.

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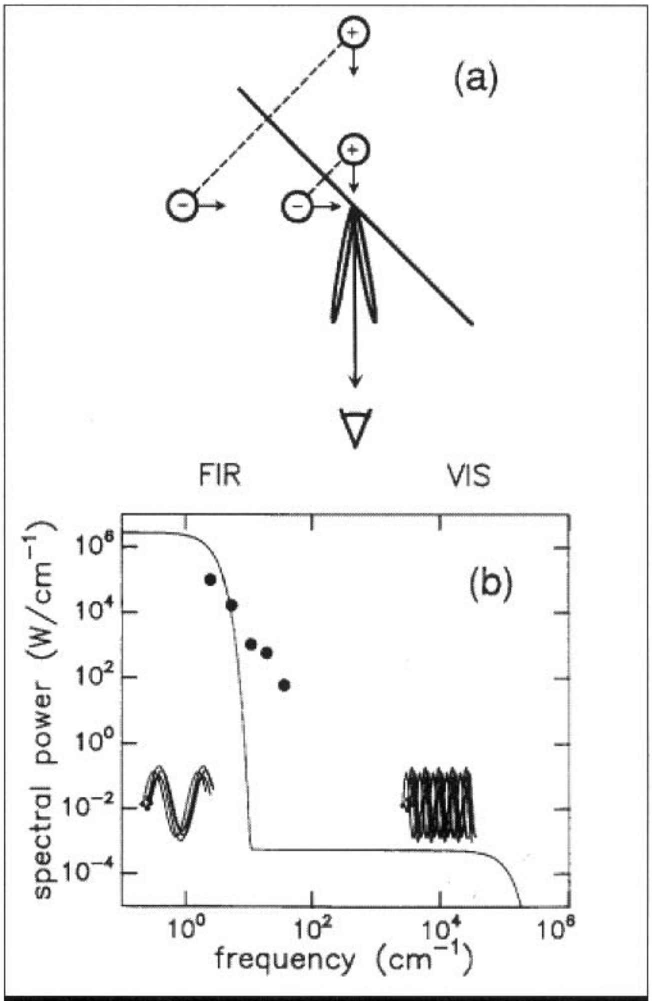

(a) Backward pattern of transition radiation for oblique incidence. (b) Frequency spectra of transition radiation. Note the difference in power between the coherent and incoherent regime. Solid dots: experimental data.

REFERENCES

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