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Observations of Regular Filamentary Plasma Arrays in High-Pressure Gas Breakdown by 1.5 MW, 110 GHz Gyrotron Pulses[1]

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Formation of regular two-dimensional plasma filamentary arrays has been observed in long open-shuttered images of air breakdown at atmospheric pressure [Y. Hidaka *et al.*, *Phys. Rev. Lett.* **100**, 035003 (2008)]. The breakdown was generated by a focused linearly-polarized Gaussian beam from a 1.5-MW, 110-GHz gyrotron with a 3-microsecond pulse length. Each plasma filament is elongated in the electric field direction and separated roughly one-quarter wavelength from each other in the H-plane. The development of this array structure can be explained as a result of diffraction of the beam around the highly conductive filaments. The diffraction generates a new electric field profile in which a high intensity region emerges about a quarter wavelength upstream from an existing filament. A new plasma filament is likely to appear at the intensified spot. The same process continues and results in the formation of the observed array. Electromagnetic wave simulations that model plasma filaments as metallic posts agree quite well with the hypothesis above. With a nanoseconds-gated ICCD camera, we directly confirmed that only a few rows of the observed array are bright at any one moment, as well as that the light emitting region propagates towards the microwave source. Further experimental breakdown research has been carried out with nitrogen, helium, and SF6 at different pressures. Although each species exhibits qualitatively different structures, in general, a lumpy plasma at high pressures transforms into a more familiar, diffuse plasma as pressure is decreased. The propagation velocity of the ionization front has been also estimated both from the ICCD images and a photodiode array. The velocity is on the order of 10 km/s, and increases as the pressure decreases and the power density increases.

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