White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***June 8, 2015***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	P
• Turbulence and transport	
• Interactions of plasmas and waves	
• Plasma self-organization	S
• Statistical mechanics of plasmas	

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	

Title:	**Intense Plasma Formation by Focused High Power Gyrotron Radiation**
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- ***Describe the research frontier* and importance of the scientific challenge.**

Recent experiments have shown that focused radiation from a pulsed, high-frequency, megawatt power level gyrotron can produce intense regions of plasma breakdown in air and other gases [1, 2, 3]. The plasmas, formed in gases at or near one atmosphere of pressure, exhibit a new phenomenon, namely the formation of ordered arrays of filamentary discharges or streamers. The nature of these self-organized plasmas is a topic of intensive theoretical research [4, 5, 6]. The filamentary arrays are only observed with powerful radiation at wavelengths of a few millimeters or less, where the discharges can be formed by focusing the intense radiation into a very small spot size, away from boundaries such as waveguides or chamber walls. The filaments are known to propagate at high speed back towards the gyrotron source. Many important parameters of these discharges remain to be studied, such as the plasma density in and near the filaments; the dependence of plasma properties on pressure and gas composition; the results of going to even higher (terahertz) microwave frequencies; the efficiency of generation of light, including UV radiation; etc. An example of a self-organized plasma is shown in the figure.

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

Advancing the frontier will require more extensive research on the properties of the plasma produced by intense gyrotron radiation, as well as the extension to higher gyrotron frequency, higher power and longer pulse length. Results so far on measurements of plasma density and temperature are inadequate to test the models that have been developed. Extension of research to higher frequencies is very important.

Very intense, small-scale plasmas can be obtained with radiation of short wavelengths since the focal spot size will scale as the wavelength squared. These intense plasma sources are of great fundamental interest as well as potentially useful for applications.

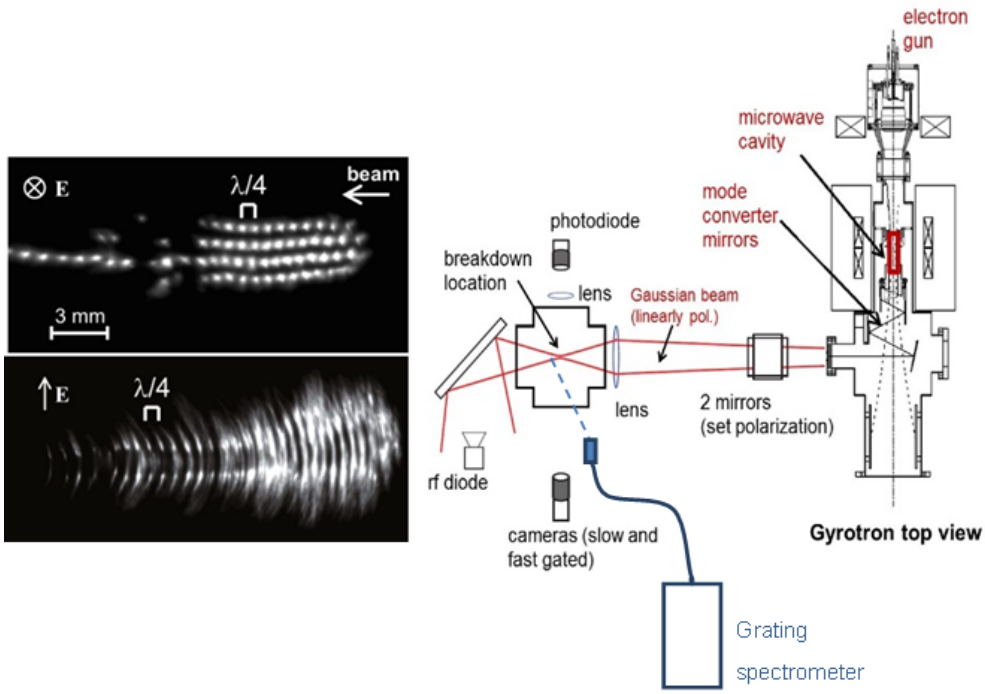

Figure: (left) Self-organized filamentary array produced in air by a focused beam from a 1.5 MW. 110 GHz gyrotron (right) schematic of the experiment.

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit.***

High frequency microwaves propagating in air are needed for advanced radar and are proposed for power beaming. The breakdown threshold for these systems must be understood for their application. Other applications include the use of gyrotron power for possible stand-off detection of ionizing radiation [7]. Intense plasmas are also proposed as sources of powerful UV or extreme UV (EUV) radiation for future lithography systems [8]. The filamentary array formed by the breakdown is a self-organized plasma. It is also a form of photonic crystal. It can be used to filter or redirect microwave radiation on a microsecond time scale. This property could be exploited to form a "plasma mirror" on a microsecond time scale for directing microwave beams in a radar transmitter. A high power, long pulse gyrotron has been tested in Japan as a practical means of rocket propulsion, with very high impulsive force [9] and a similar concept is being studied experimentally by NASA.

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