Scattering Effects of Millimeter Wave Beams In 110 GHz Air Breakdown Plasma.
Matthew VandeSande

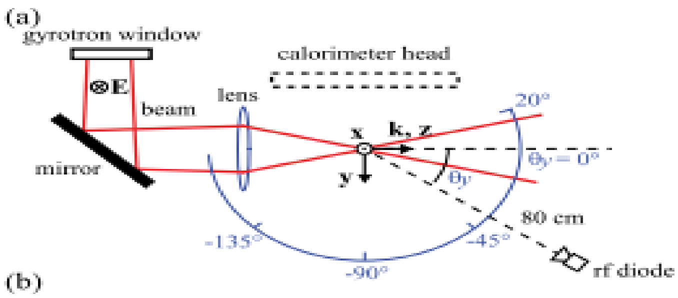
Leading areas in plasma science are focusing on megawatt-level millimeter wave beams that are produced by gyrotrons. Dr. Alan M. Cook, Dr. Jason S. Hummelt, Dr. Michael A. Shapiro and Dr. Temkin at the University Of Massachusetts Institute Of Technology are analyzing the diffraction and scattering of a focused 110 gigahertz wave beam. The researchers focused on measuring the effects from scattering and transmission of the beam through a plasma breakdown. By focusing polarized wave beam through a polyethylene lens onto a pin hole, they were able to generate their results using a radiofrequency diode and a calorimeter. The group of researchers published their experimental findings in the April version of the Journal of American Institute of Physics.

Currently researchers are actively working on analyzing properties of plasma and how they could be applied. Within the universe plasma is the most observed state of matter and in our society the least applied out of the known four. Creation of plasma will generate an electric current within which can be affected by an electromagnetic field. Application of magnetic fields has been well known to researchers, that leading topics are tending toward applying plasma to fusion, medicine and plasma acceleration. Further research in this field will provide extremely beneficial toward space discovery, modern technology and scientific research (spectroscopy and interferometry).

Along with solids, liquids and gases, plasma is known as one of the four states of matter. Generation of plasma happens once a gas gets heated and the molecules become ionized. With the presence of numerous charged ions, plasma can be affected strongly by an electromagnetic field. Plasma does not take on a certain shape or specific structure but can be formed into beams, shapes and layers with the manipulation of a magnetic field. In modern society, plasma can be seen daily in such things as lightning, plasma TV displays, welding arcs and accretion disks.

In the experiment the researchers use a gyronton; a gyrotron is a device that uses high powered vacuum tubes to generate a high frequency millimeter wave. Known also as a free electron maser (microwave amplification by stimulated emission of radiation), it has the ability to generate high power at millimeter wavelengths. Experimental and analytical results from determining scattered and transmitted power of our wave will have important effects on the applications of millimeter wave radiation.

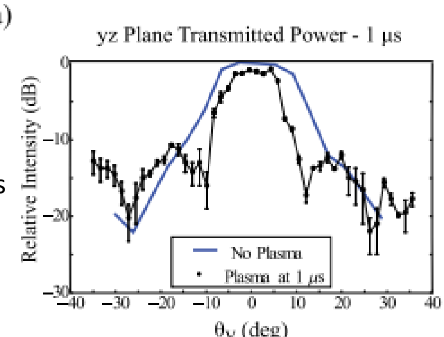
The researchers were able to find their results by using an experimental setup that could measure diffraction and scattering of our system. Their apparatus used a 110 gigahertz, 1.5 megawatt gyrotron window capable of generating a linearly polarized millimeter wave beam. Carefully they were able to change the polarization by reflection of our wave beam off a mirror. The new polarized wave beam goes through a polyethylene lens and focused onto a small pin hole (approximately 5 millimeters) which is centered on top of a rotating arm. With the use of a calorimeter head and a radiofrequency diode mounted the rotating arm; analysis of transmitted and scattered power was completed at various observation angles. The researchers found that when our wave beam and rf diode is offset on an angle of <10 degrees, the transmitted power of our beam decreases monotonically. When the angle is offset by 10-45 degrees, the beam will produce a high or law power level depending on the time of our pulse. When the angle is offset >45 degrees, power peaks were found to be weaker than 10-45 degrees. Using the measurements from the diode, the researchers determined that the plasma breakdown scattered of 1% of our incident peak power into a backward cone of ±7°.

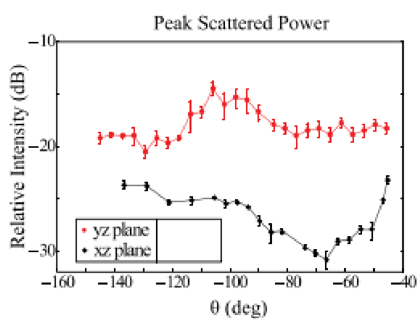


Analysis of the transmitted power of our wave beam through our plasma breakdown was measured and comparable against transmitted power with no breakdown.

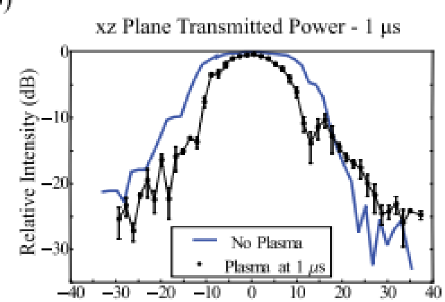
By looking at the diagrams below and to the right, we see that when the plasma breakdown is added to the setup transmitted power is lose due to scattering. However as expected the researchers saw that transmitted power contains a higher intensity peaks at angle ±25 degrees and greater thanwithout our plasma breakdown. By examining the plot below, the researchers deduced that the scattering reached high peak levels at 100 degrees and low peak levels at 70 degrees.

a)



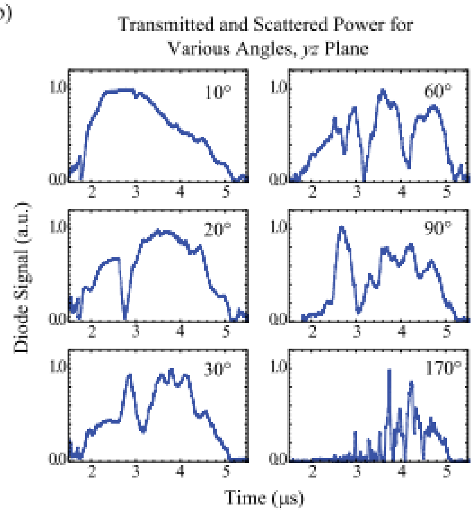


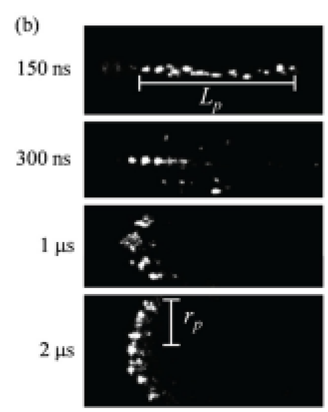
b)



The researchers from MIT also measured the transmitted power of our wave beam through the plasma breakdown at various angles. Depiction of this is shown in the graph below where the researchers have shown the transmitted and scattered power on our diode detector versus time. Here we see again that the between angles 10-45 degrees, the transmitted and scattered is the highest. They concluded peak scattered power occurs at 100 degrees in the yz plane, and occurs at 70 degrees in the xz plane.

(b)





Further research in plasma science could provide beneficial through manipulation of their electric current toward the generation of electromagnetic field and usable power. The researchers from MIT focussed on determining the effects of back scattering on the power peaks. Providing analysis on the loss of power due to scattering will provide support further research in applied plasma science. Using a device called a tokamak, researchers can look at focusing plasma propulsion onto atmospheric air. Using a tokamak, plasma can be confined magnetically in the shape of torus and frequently researched devices for producing thermonuclear fusion power. Others researchers in this field are looking at the effects plasma has in nature (earth's ionsphere, astrophysical plasma), plasma theory (interaction with waves/beams), industrial plasmas (chemistry, sources) and applications of plasmas (tokamak, magnetic fusion energy).

RSS Feed

Researchers at the Univsity of Masscauetts Insititute of Technology are attempting to yeild results in the analysis of scattering and transmission of millimeter wave through a plasma breakdown medium. Leading the team, Dr. Alan M. Cook has been able to analyze the scattering effects on millimeter wave radiation specifically observing the loss of power cause by this effect. Focusing on the diffraction and reflection properties the reserachers devised a way to yeild high transmitted power peaks using a calorimeter and a radiofrequnecy diode at angles ranging from 10 degrees to 45 degrees.

Interview Questions

Correspondance of the letter was sent to hummelt@mit.edu

1) Can you briefly explain your path through school? Toward your career at MIT.
2) Why are you interested in plasma sciences?
3) What other research areas do you have?
4) Can you explain more in depth about the diffraction that occurred in your experiment?
5) What can we do this information in applying to real world?
6) What effects would have a 200 GHz beam instead of a 110 GHz?
7) How would change the beam polarization and plasma size for further research?

Answers to be emailed upon reply from correspondance.