AWA Needs and Opportunities Workshop
chaired by Manoel Conde (Argonne), John Power (Argonne National Lab)
from Wednesday, August 21, 2019 at **13:00** to Friday, August 23, 2019 at **12:00** (US/Central)
at **Argonne, Building 360 (A-224)**

Plasma Dielectric Wakefield Accelerator

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Yale University Columbia University NSC KIPT Omega-P R&D, Inc. Accelerator Physics & Technology

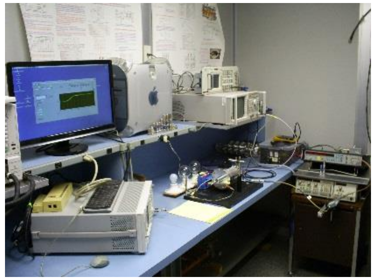
(AWA) to provide “plasma diagnostic”

-- possible types

1) Microwave cavity over an open section of DWA;

2) Interferometer (e.g. Mach-Zehnder) based;

3) Using Schlieren

1)


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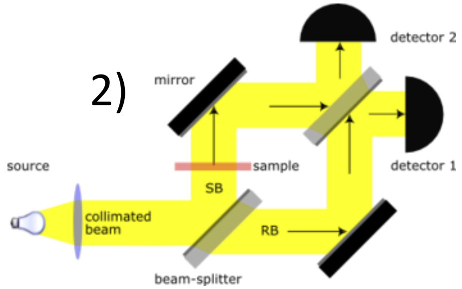

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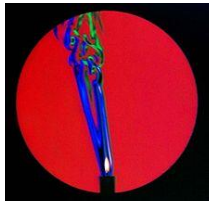

1) the average plasma density is measured by the microwave resonator method (probably at 12GHz);

2) to pass an IR or visible laser beam down the axis of the PDWA;

the plasma would form a leg of an interferometer to count fringes;

3) some information about the radial electron density profile using schlieren (advanced shadowgraph)

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Analytical and numerical studies of underdense and overdense regimes in plasma-dielectric wakefield accelerators

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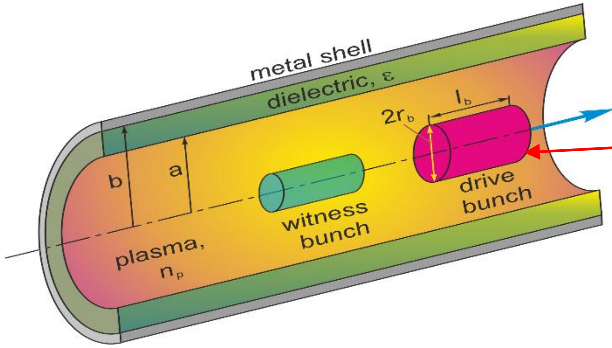
ARTICLE INFO

Keywords:
Wakefield
Acceleration
Blowout
Underdense plasma
Overdense plasma
Particle-in-cell

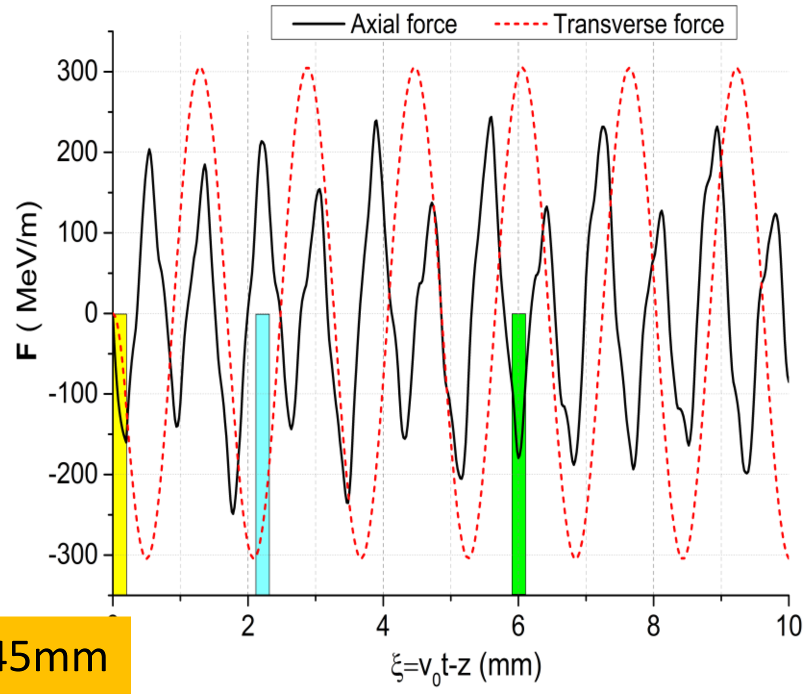
ABSTRACT

We present the results of analytical studies and numerical simulations of a plasma-dielectric wakefield accelerator (PDWFA). The plasma-dielectric structure under investigation is a dielectric-lined circular waveguide that has a transport channel filled with isotropic plasma. In the linear theory approximation (overdense plasma) the total field is represented as a sum of the plasma wave, the eigenwaves of the dielectric waveguide, and the quasistatic field of the bunch. It is shown that at a certain plasma density the superposition of the plasma wave and the dielectric waves allows the acceleration of the witness bunch by the field of the dielectric wave together with simultaneous focusing by the plasma wave. For the overdense plasma regime the results of analytical investigations coincide well with results of particle-in-cell (PIC) simulations. Also, we carried out a PIC simulation of the underdense (blowout) regime of wakefield excitation in the unit. In this regime a focusing is provided by ions remaining in the drift channel after pushing out from it plasma electrons.

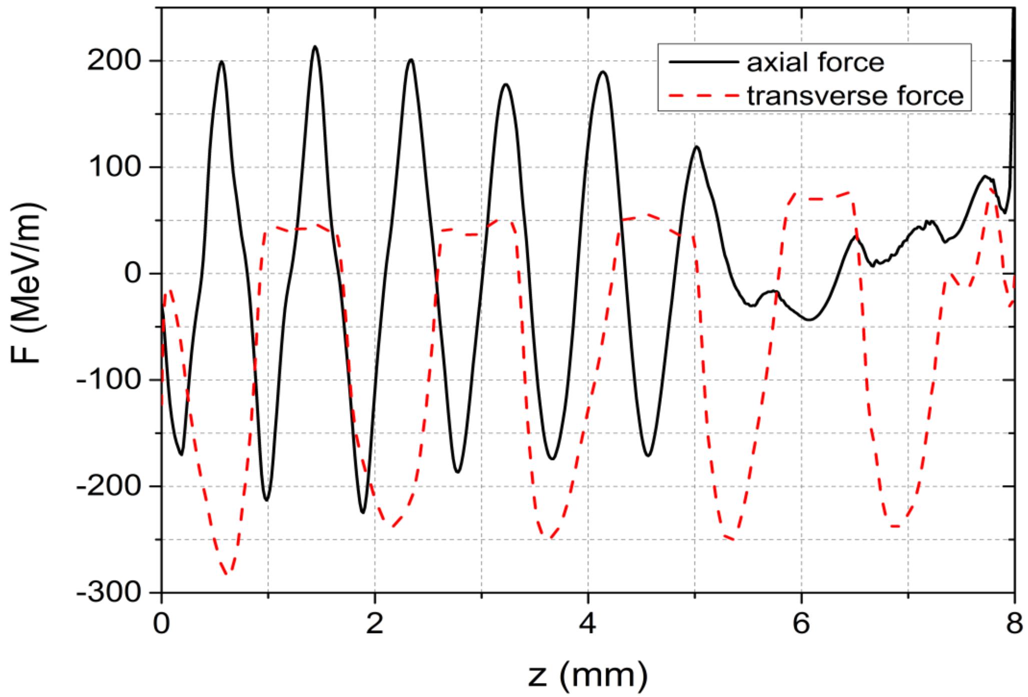


one drive,
or a few

outer radius of dielectric tube	600 microns
inner radius of dielectric tube	500 microns
relative dielectric constant, ε (fused silica liner)	3.75
drive bunch charge	3 nC
drive bunch length, L_b (box distribution)	200 microns
drive bunch radius, r_b (box distribution)	450 microns
drive bunch electron density, n_b	1.47×10^{14} cm^{-3}
n_b/n_p	1/3



@ r=0.45mm



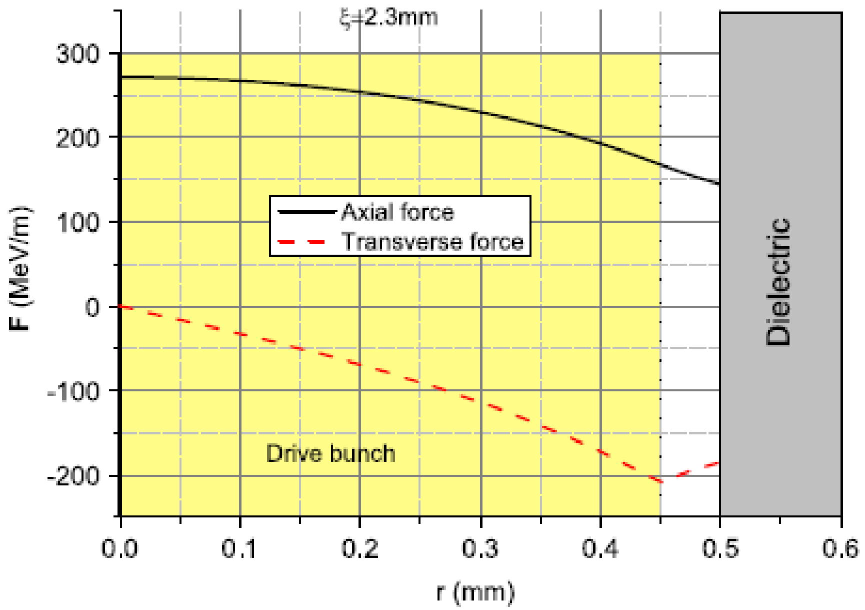
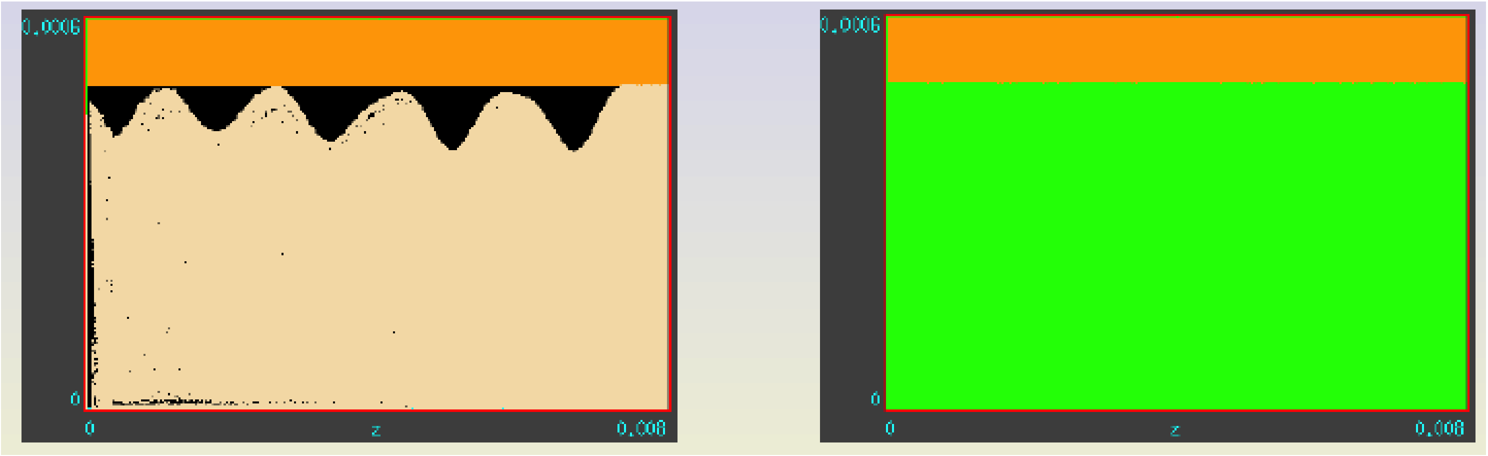
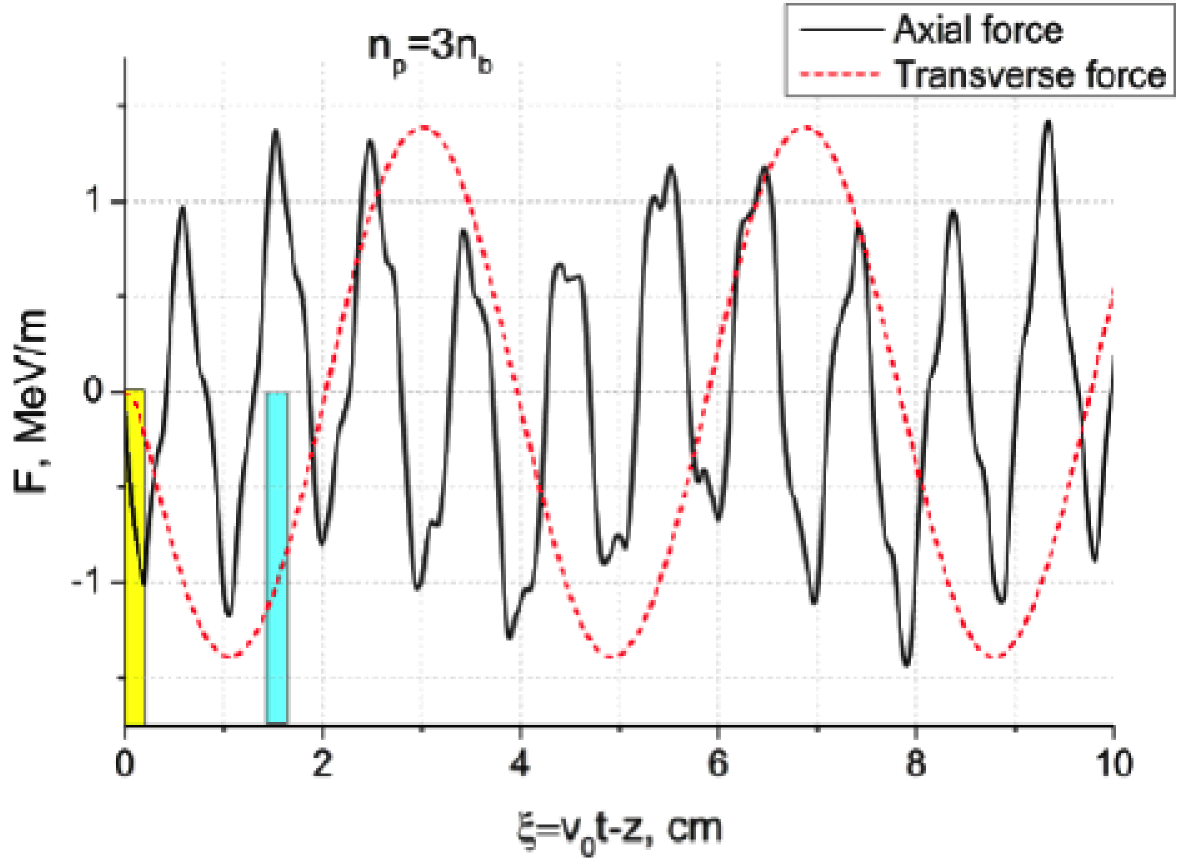


Fig. 4. Transverse profile of the longitudinal force (black solid line) and transverse force (red dashed line), acting on a witness electron, located at a distance of 2.3 mm ($\xi \equiv v_0\tau = v_0 t - z$) from the head of the drive bunch. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)



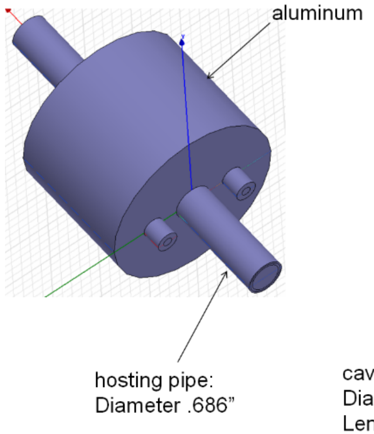
Configuration space (*r*, vertical; *z*, horizontal; dimension unit is meter) plot of the electrons (left figure, tan shading representing computed discrete dots for particles) at t = 26.7 psec; dielectric wall is shown in orange. In the right figure, positive ions (green shading) are shown. The drive bunch is at the right-hand side of the figures, and the wakefield trails left. The transverse force has pushed plasma electrons to the wall in the wavy black region adjacent to the wall that remains filled with positive ions, thereby producing the periodic plasma wave. Plasma fills the entire unit up to the dielectric wall.

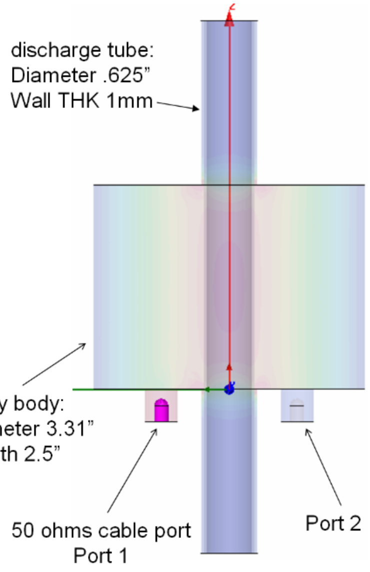
OD of dielectric tube	10.22 mm
ID of dielectric tube	8.0 mm
relative dielectric constant, ε (fused silica)	3.75
drive bunch charge	1 nC
drive bunch length, L_b (box distribution)	2.0 mm
drive bunch radius, r_b (box distribution)	2.0 mm
drive bunch electron density, n_b	2.5×10^{11} cm^3
plasma radius n_b/n_p	4.0 mm 1/3

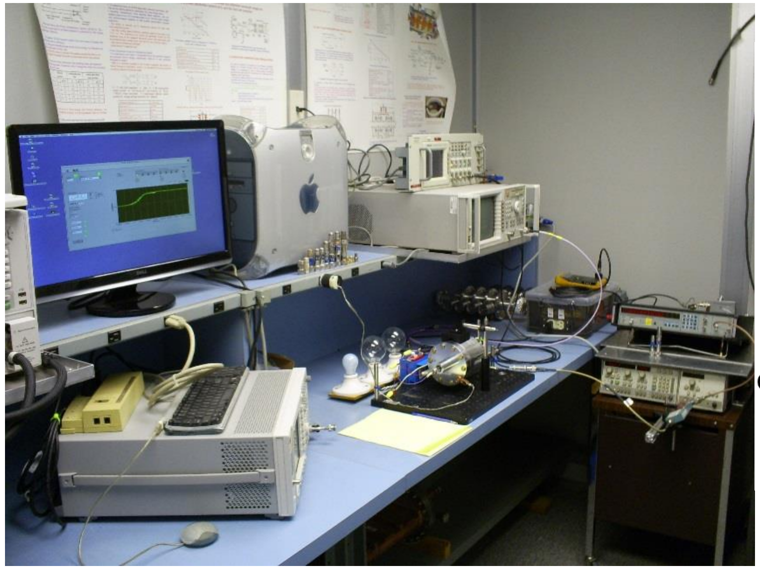


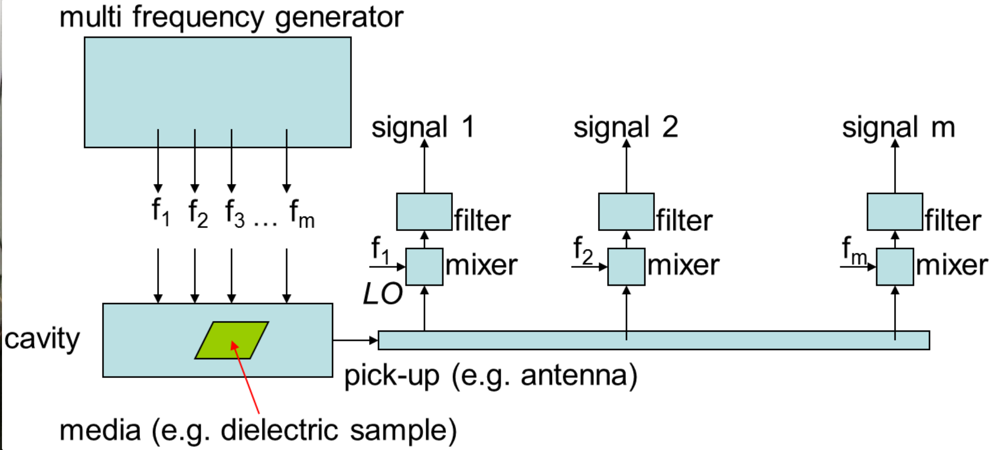
Thus, an experiment conducted at AWA could provide validation of this concept as a high energy accelerator, even though the predicted acceleration gradient is not high, but the motion of test particles distributed at a typical witness bunch location shows focusing action upon sample particles following the drive bunch at the location of the witness bunch…

1 -- Microwave cavity over an open section of DWA



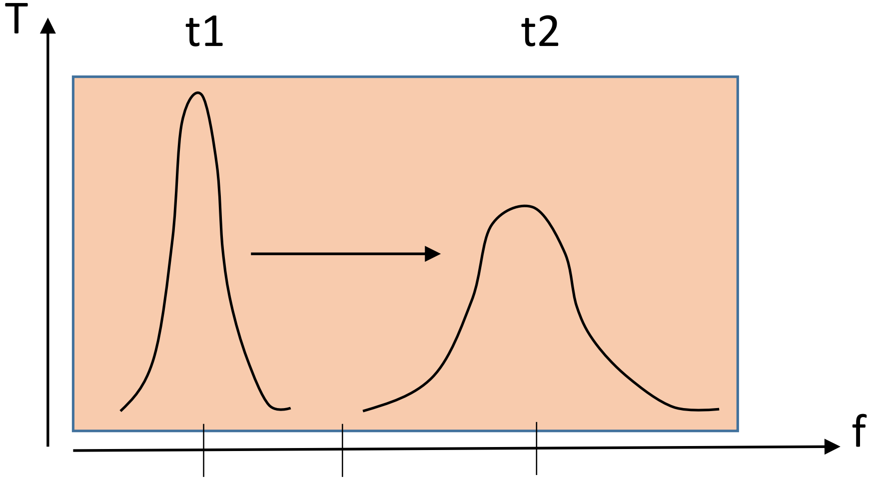


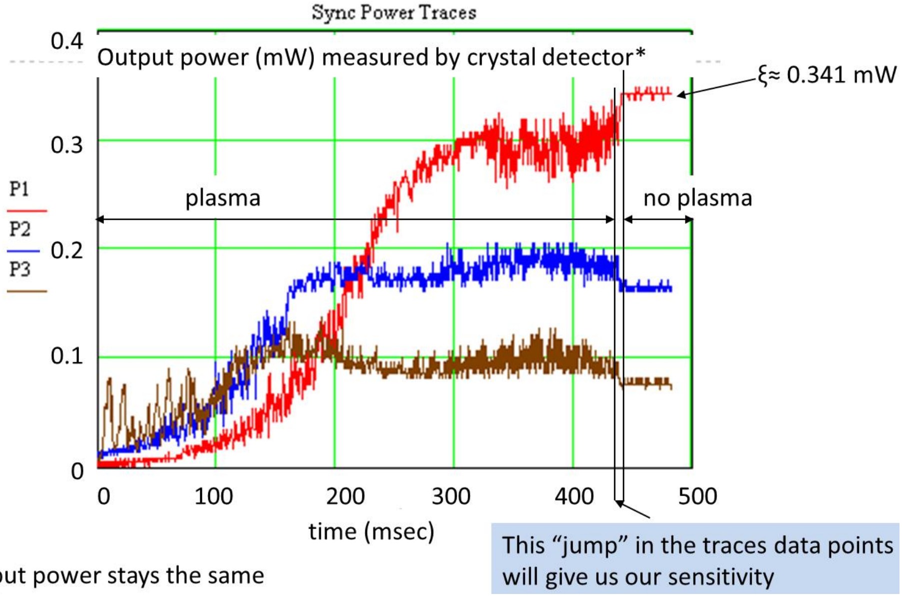




Traces were recorded at three observer frequencies:

f1 = 2479.1936 MHz (≈ resonant frequency) (RED)
f2 = 2480.276 MHz (BLUE)
f3 = 2481.141 MHz (BROWN)

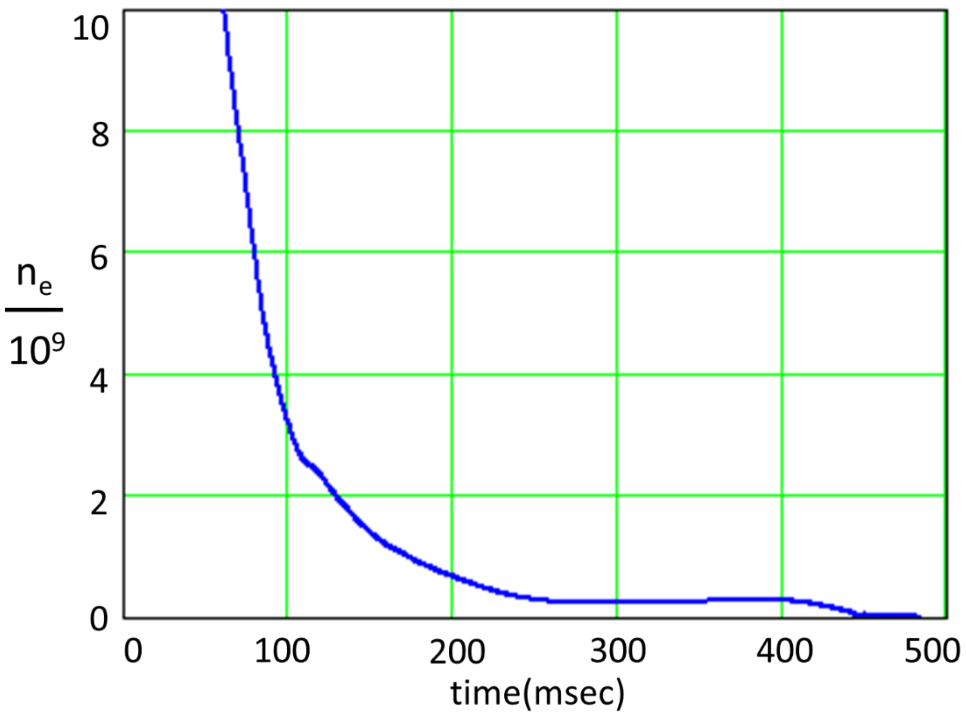


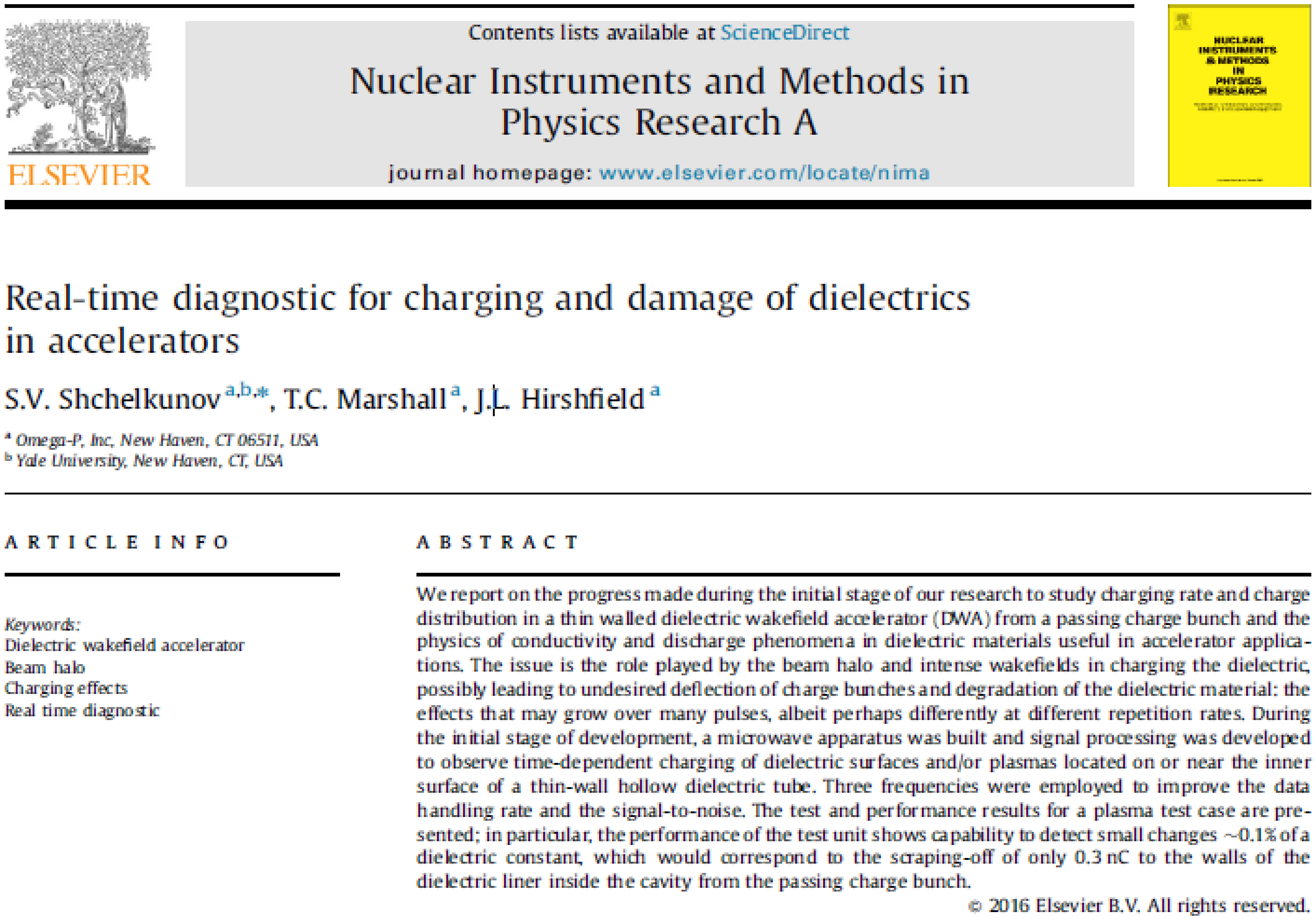


*Input power stays the same

$$\varepsilon_{\mathrm{Re}} = 1 - \frac{n_e \cdot e^2}{m_e \varepsilon_0 (2\pi F_\xi)^2} \frac{1}{1 + (F_{coll}/F_\xi)^2}$$

$$\varepsilon_{\mathrm{Im}} = \frac{n_e \cdot e^2}{m_e \varepsilon_0 (2\pi F_\xi)^2} \frac{F_{coll}/F_\xi}{1 + (F_{coll}/F_\xi)^2}$$

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Real-time diagnostic for charging and damage of dielectrics in accelerators

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ARTICLE INFO

Keywords:
Dielectric wakefield accelerator
Beam halo
Charging effects
Real time diagnostic

ABSTRACT

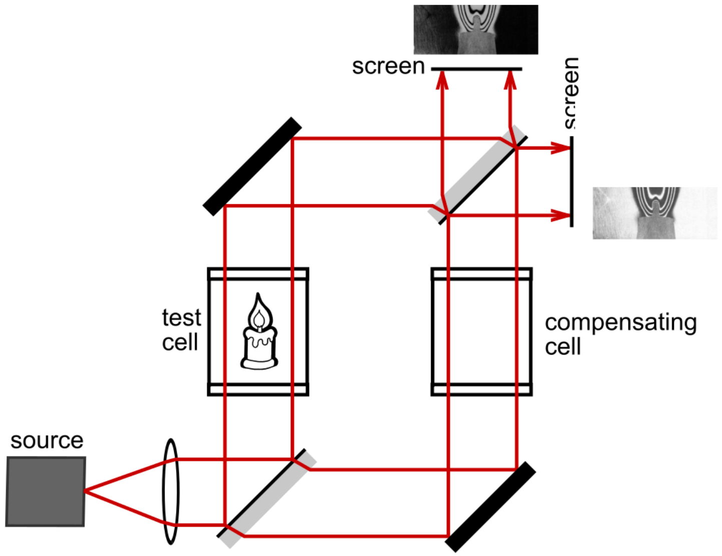
We report on the progress made during the initial stage of our research to study charging rate and charge distribution in a thin walled dielectric wakefield accelerator (DWA) from a passing charge bunch and the physics of conductivity and discharge phenomena in dielectric materials useful in accelerator applications. The issue is the role played by the beam halo and intense wakefields in charging the dielectric, possibly leading to undesired deflection of charge bunches and degradation of the dielectric material: the effects that may grow over many pulses, albeit perhaps differently at different repetition rates. During the initial stage of development, a microwave apparatus was built and signal processing was developed to observe time-dependent charging of dielectric surfaces and/or plasmas located on or near the inner surface of a thin-wall hollow dielectric tube. Three frequencies were employed to improve the data handling rate and the signal-to-noise. The test and performance results for a plasma test case are presented; in particular, the performance of the test unit shows capability to detect small changes ~0.1% of a dielectric constant, which would correspond to the scraping-off of only 0.3 nC to the walls of the dielectric liner inside the cavity from the passing charge bunch.

The lower electron density limit can be improved by increasing the cavity Q-factor. This follows from the fact that, at low densities of free electrons, $n_e \sim BW_\xi$. In our present setup, Q ~1000, and the minimum density $n_{e,\ min} \sim 10^8$ cm^{-3}; If one works, however, with Q ~3000-5000, this will still allow us to capture the processes on the *micro*-sec time-scale, yet to detect $n_{e,\ min}$ $2 \div 4 \times 10^7$ cm^{-3}.

2 -- Interferometer (e.g. Mach-Zehnder) based

The Mach–Zehnder interferometer's relatively large and freely accessible working space, and its flexibility in locating the fringes has made it the interferometer of choice for visualizing flowin wind tunnels[6][7] and for flow visualization studies in general. It is frequently used in the fields of aerodynamics, plasma physics and heat transfer to measure pressure, density, and temperature changes in gases.

From Wikipedia, the free encyclopedia



3 -- Using Schlieren

A typical application in gas dynamics is the study of shock waves in ballistics and supersonic or hypersonic vehicles. Flows caused by heating, physical absorption[6] or chemical reactions can be visualized. Thus schlieren photography can be used in many engineering problems such as heat transfer, leak detection, study of boundary layer detachment, and characterization of optics.

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