Wakefield Breakdown Test of a Diamond-Loaded Accelerating Structure

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Argonne Wakefield Accelerator

euclid TECHLABS

Argonne NATIONAL LABORATORY

AWA facility (current)

- 1 ½ cell L-band Injector
- Magnesium photocathode (QE = 10^{-4})
- Linac: standing wave π/2 mode L-band
- Beam energy 14 MeV
- Charge: 1 – 100 nC (reached 150nC)
- Bunch train operation with 4 bunches x 25 nC (or 16 bunches x 5 nC)
- 2 – 2.5 mm bunchlength
- Emittance < 200 mm mrad (at 100 nC)
- High Current: ~ 10kA

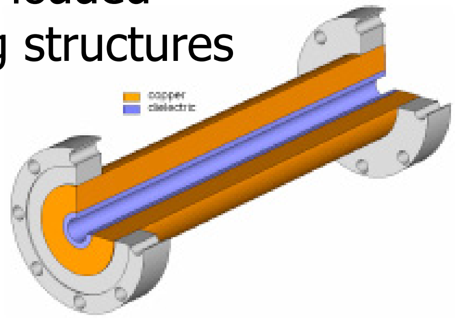
Experimental program:

- High brightness beam
- Wakefield acceleration in DLA
- Power generation and extraction
- Phase space manipulation
- Beam diagnostics

AWA facility upgrade

- Additional RF gun with Cesium Telluride photocathode (QE > 1%)
- Six additional π mode linac tanks
- Beam energy will increase to 75 MeV
- Bunch train operation with 32 bunches x 60 nC (or 10 bunches x 100 nC)
- Beam power of 5.9 GW (or 10 GW)
- Witness beam to probe wakefields generated by drive beam

<u>100 MV/m generated</u> in dielectric loaded accelerating structures



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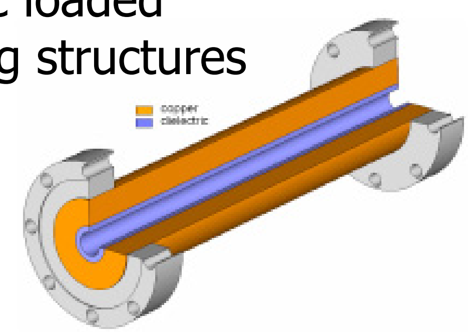
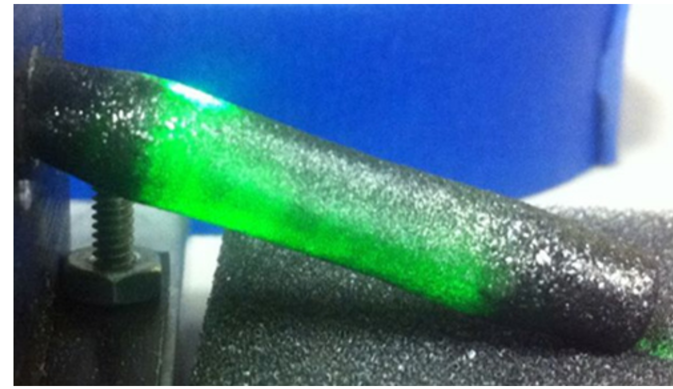


Why Diamond?

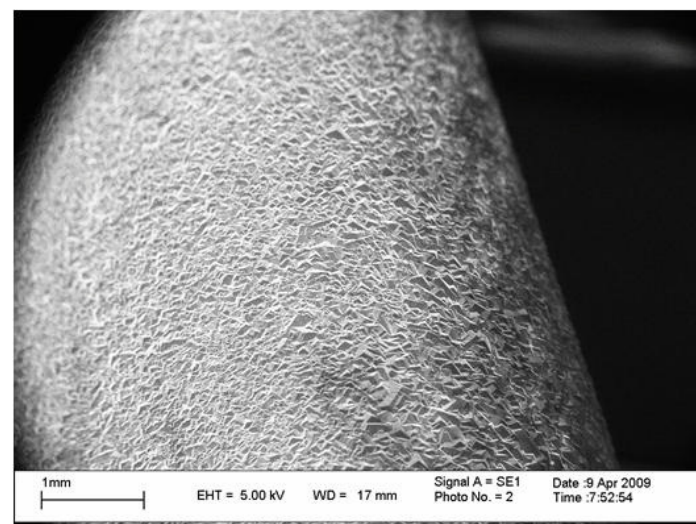
CVD DIAMOND PROPERTIES:

- DC BREAKDOWN THRESHOLD OF ~ 1 GV/m
- LOSS FACTOR DOWN TO 5×10^{-5} AT 30-140 GHz
- HIGHEST THERMAL CONDUCTIVITY ($2\cdot10^{3}\ Wm^{-1}K^{-1}$)
- MULTIPACTING CAN BE SUPPRESSED (termination: surface oxydation)

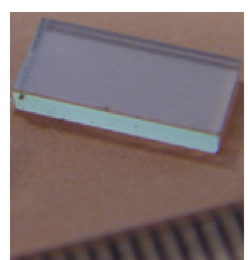


and

CVD DEPOSITION NOW CAN BE USED TO FORM CYLINDRICAL WAVEGUIDES



PLANAR DIAMONDS ARE AVAILABLE COMMERCIALLY IN VARIOUS GRADES (SINGLE CRYSTAL)

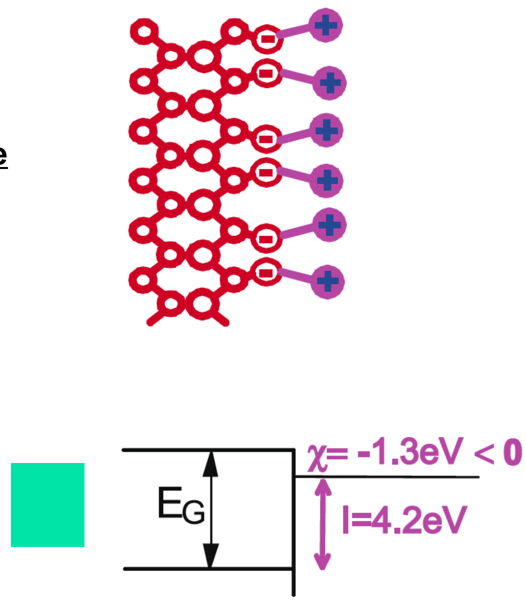


GHz (AWA) – THz (FACET)

Diamond Surfaces:
Stable and Accessible Electron Affinity Control

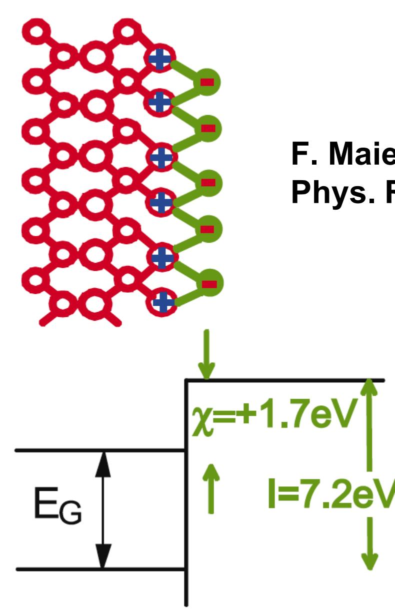
B.B. Pate, Surface Science 165(1): 83-142 (1986)

H-terminated surface



Negative Electron Affinity
Supports Floating Electrons

O-terminated surface



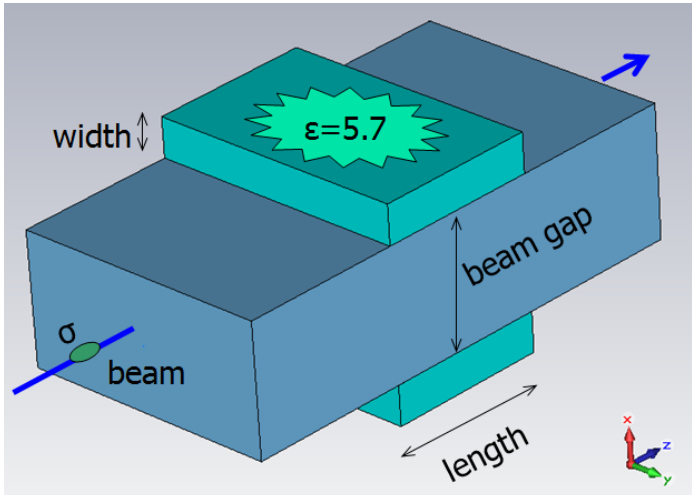
Positive Electron Affinity

F. Maier, J. Ristein, L. Ley, Phys. Rev. B 64, 165411/1-7 (2001)

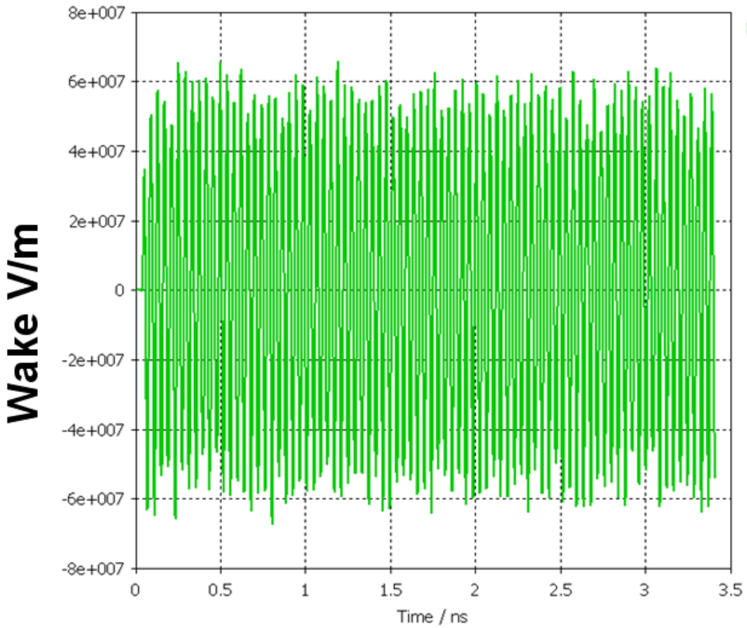
3 eV variation in Electron Affinity
Largest known variation; unique to diamond

Introduction

Our goal is to perform first WF experiment with Diamond-based DLA, test for breakdown



50MV/m per 50 nC beam



Bunch length	**1.5 mm**
Beam gap	**4.0 mm**
D thickness	**1.2 mm**
width	**8 mm**
length	**5.0 mm**

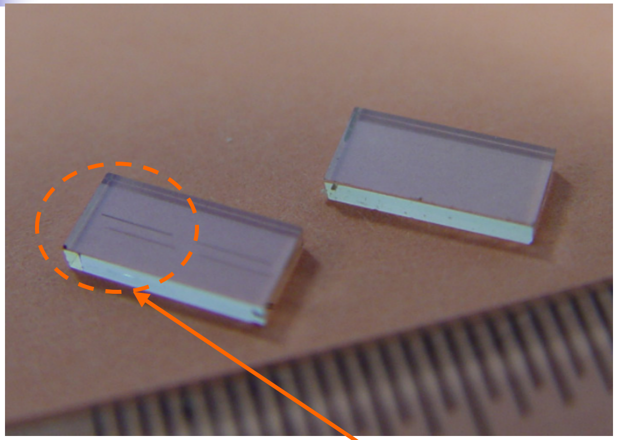
***AWA facility can generate up to 100nC beam with σ_z = 2.5 mm (14 MeV)**

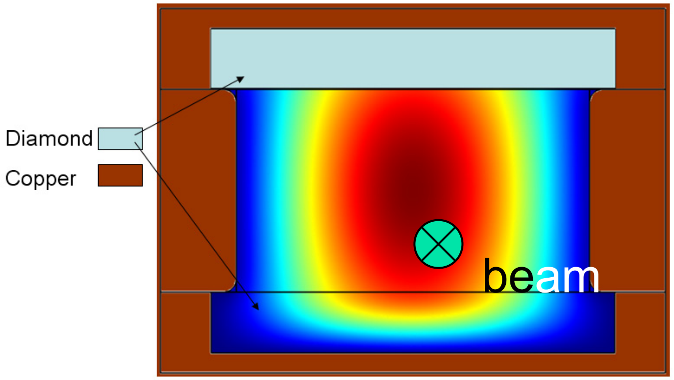
Structure is short, TM_{110} – based

Wake is a single mode at ~ 26 GHz

Q = 2800

Field Enhancement in the scratch

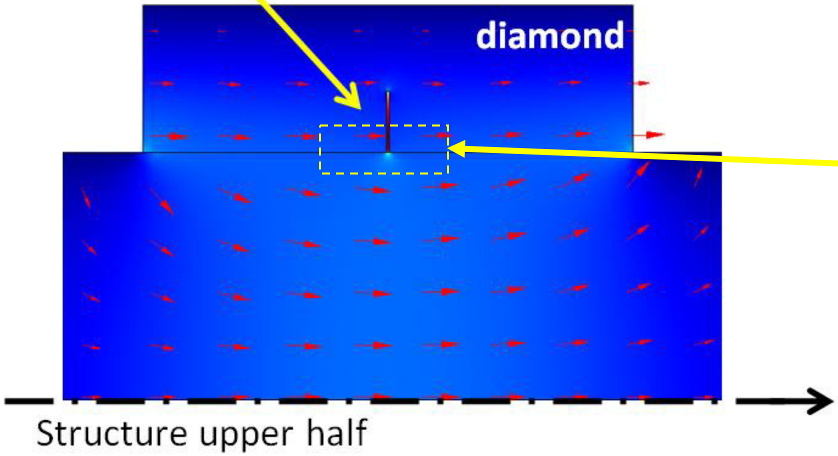




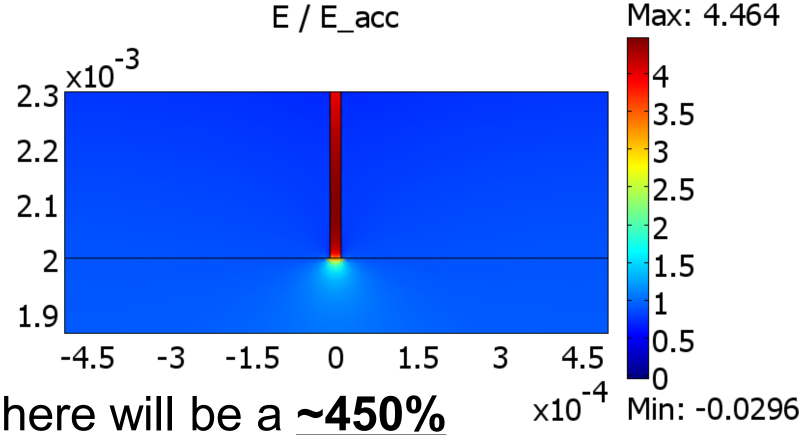
Avoiding hot spots on diamond holder

Diamonds (E6) ...**scratched**

50nC → 250 MV/m



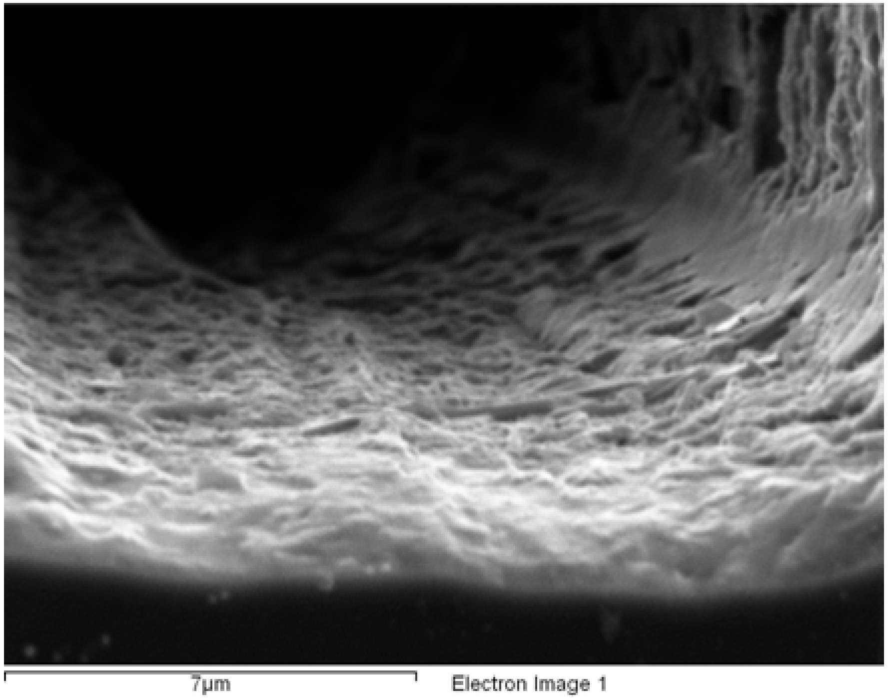
beam



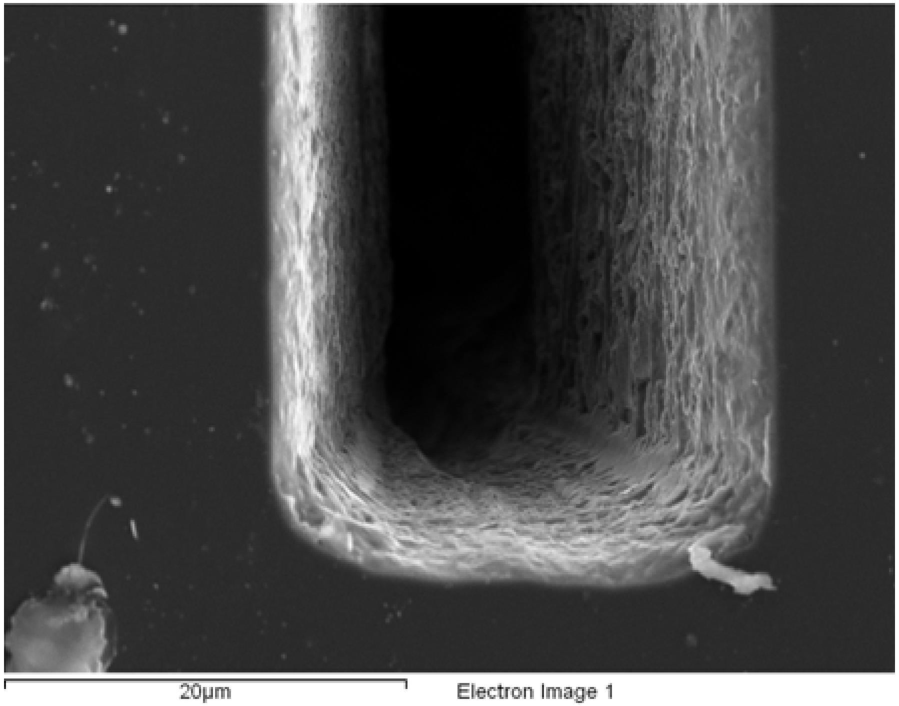
There will be a **~450% field enhancement** in the scratch

Diamond groove SEM image

Image: “BEFORE”

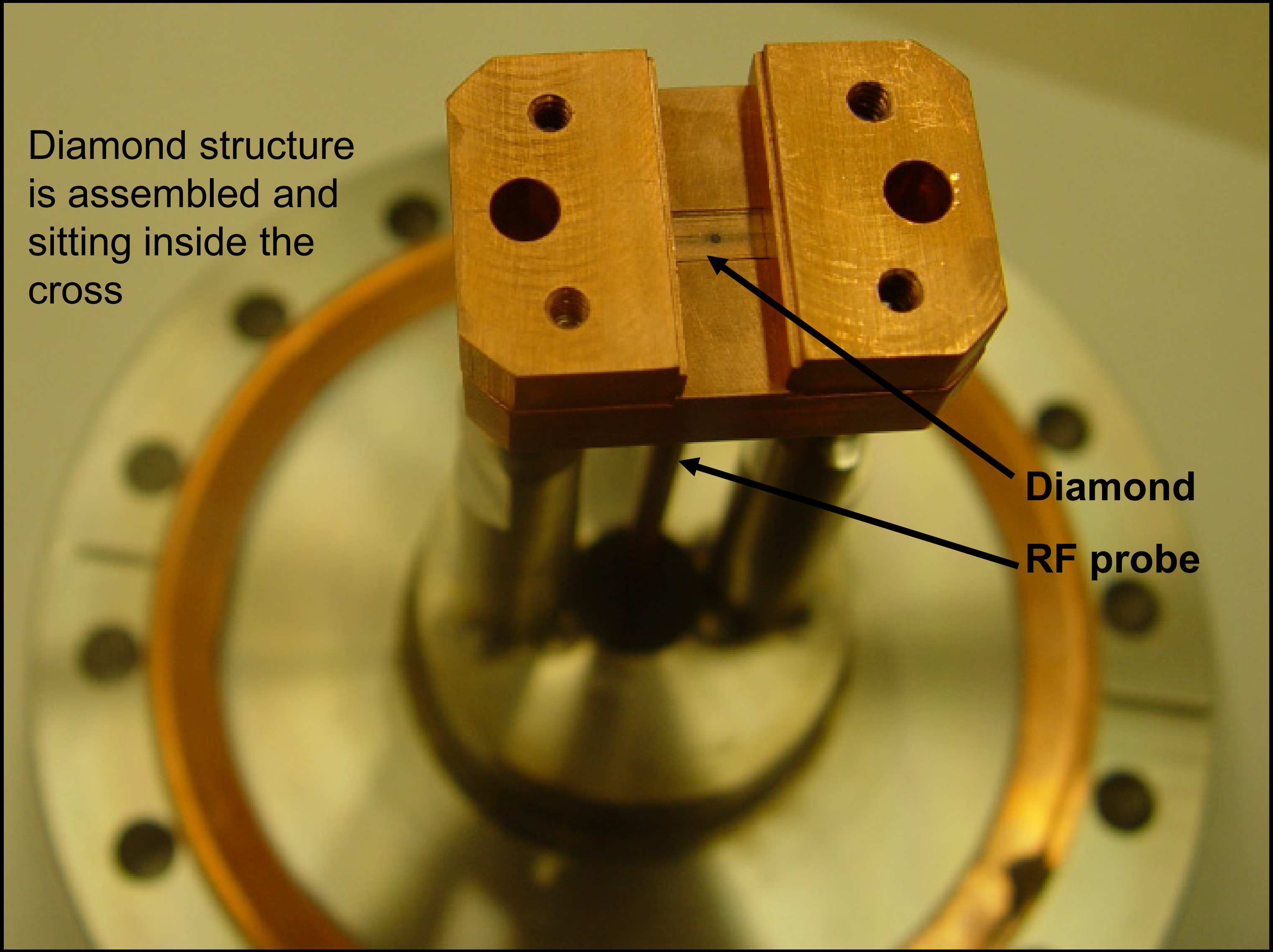


7 micron



20 micron

Diamond Holder



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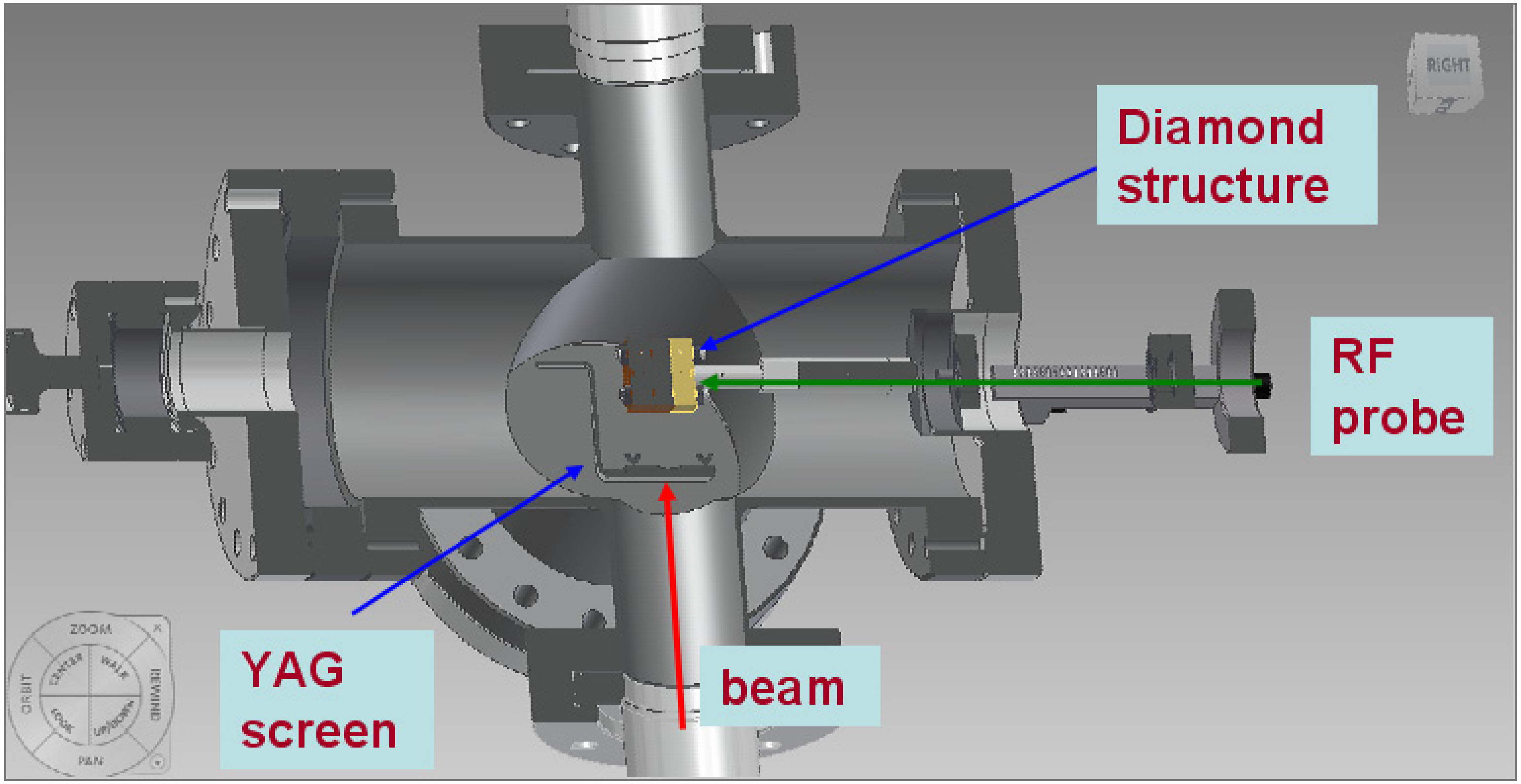
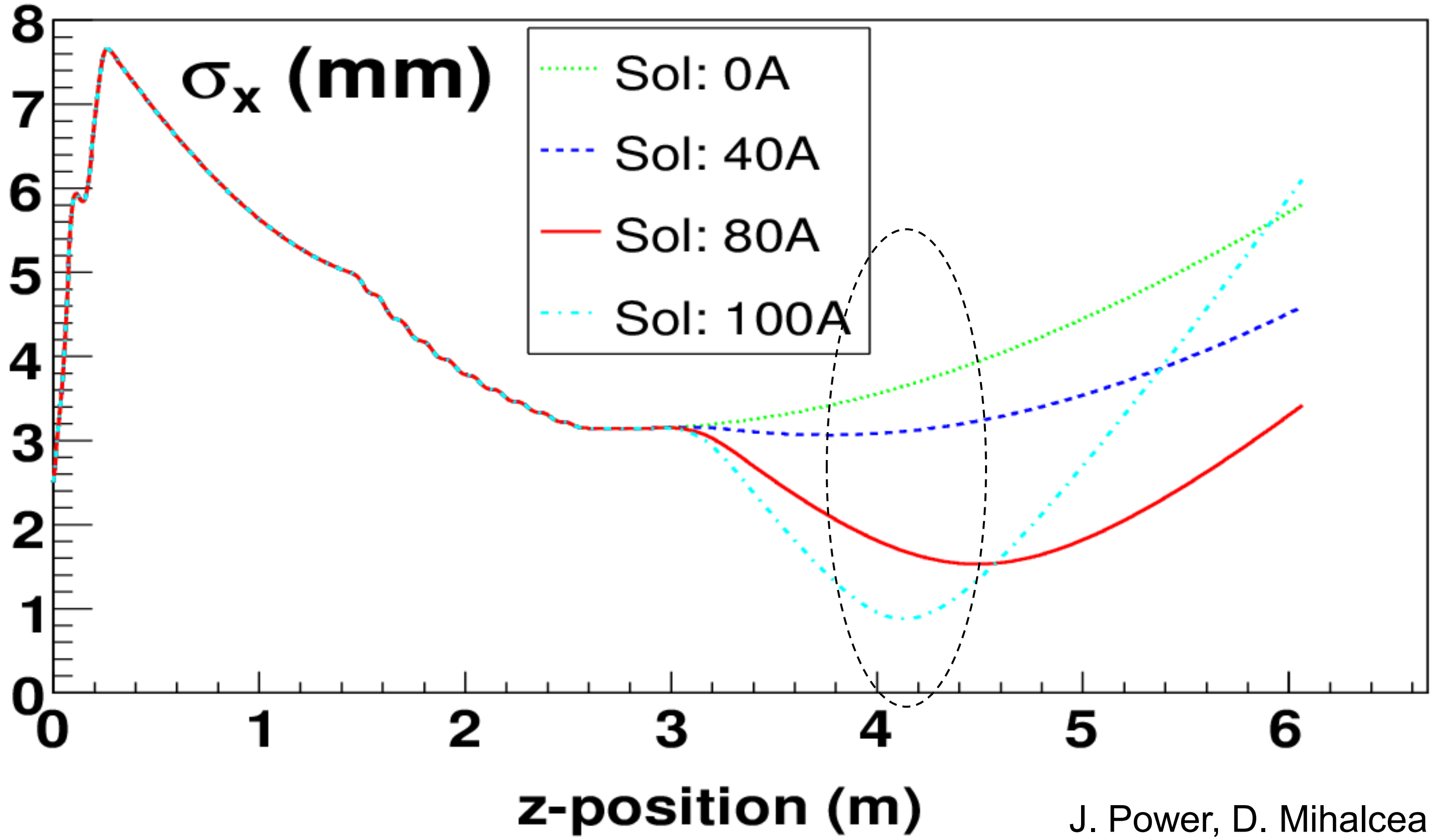


Beam Transport



J. Power, D. Mihalcea (AWA)

Summary

- A dielectric-loaded accelerating structure is designed to put the surface of the diamond under high field (~250 MV/m, ~50ns per 50nC beam)
- SEM analysis of the diamond surface is performed prior to the experiment
- Experiment is scheduled at the AWA (wake measurement)
- There will be a post-experiment SEM analysis performed to identify any changes on the diamond surface
- Further experiments at FACET (THz, GV/m)