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ADVANCES IN BEAM TESTS OF DIELECTRIC BASED ACCELERATING

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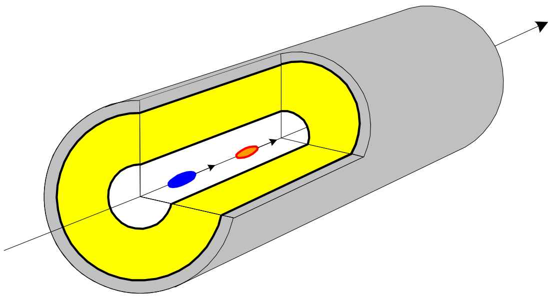
Outline

We present here three experiments carried out at the ATF, AWA and FACET – a direct wakefield acceleration and high gradient generation.

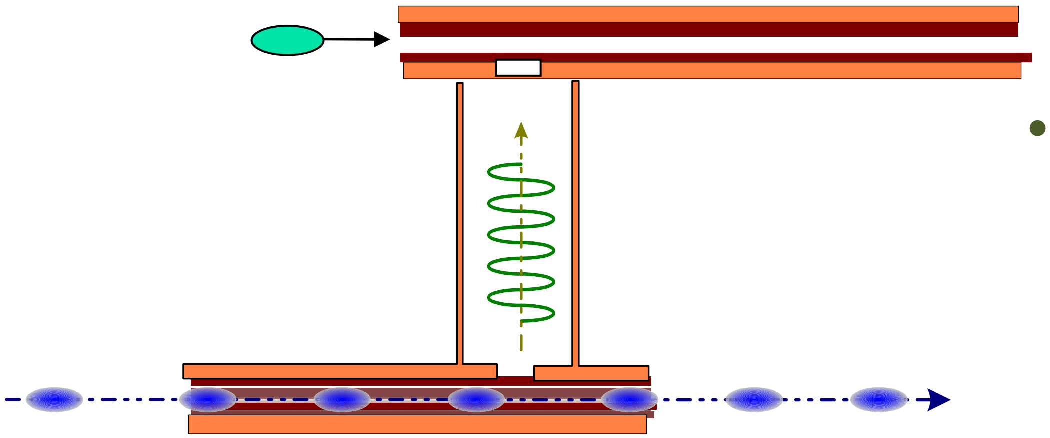
- High gradient material test with the Ka-band diamond based structure.
- A demonstration of a direct wakefield acceleration with the THz diamond based structure.

Motivation

$$W_z(z) \approx \frac{Q}{a^2}\ \exp\left[-2\left(\frac{\pi\,\sigma_z}{\lambda_n}\right)^2\right]\cos(kz)$$

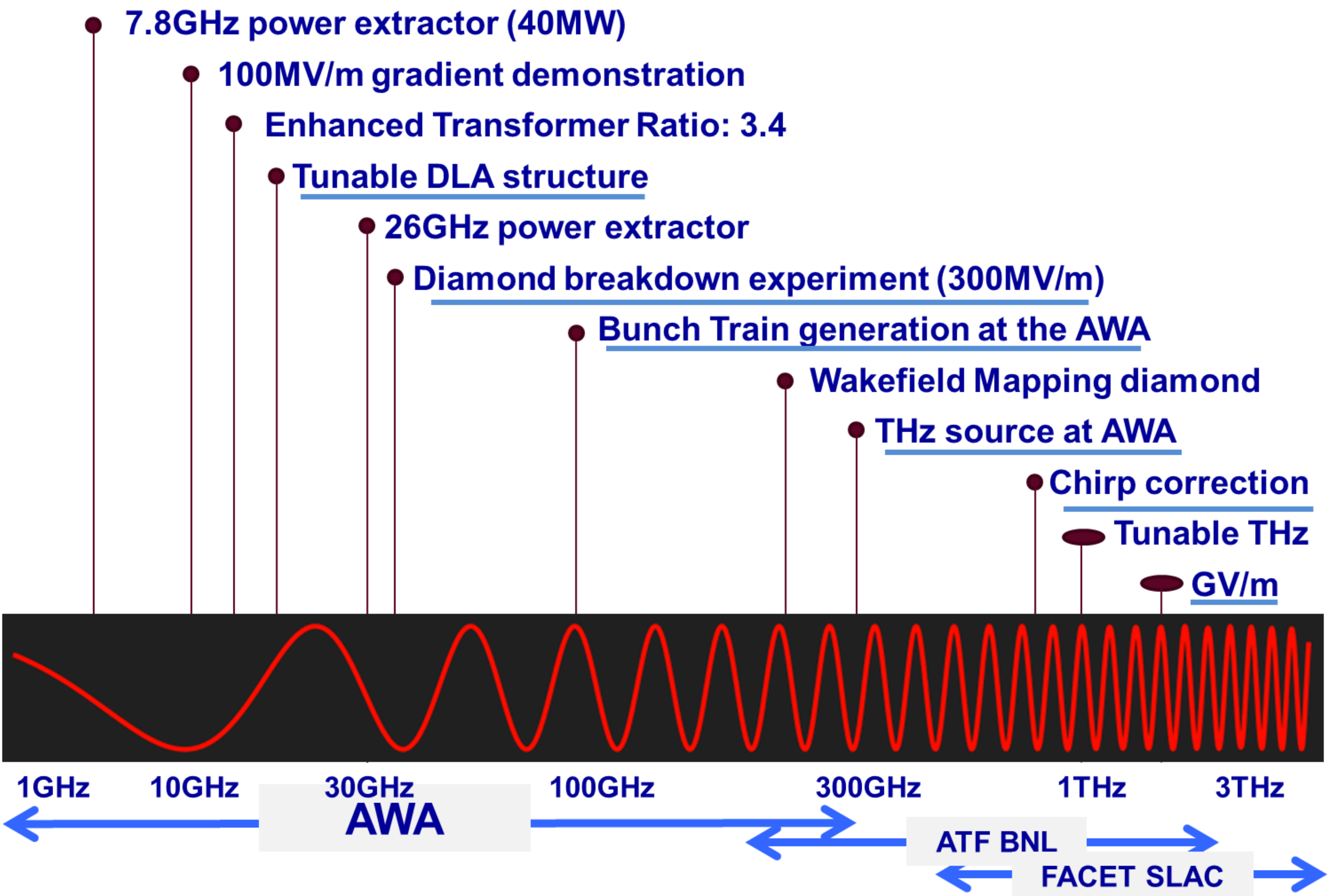


$$\sigma_r = \left(\frac{\varepsilon_N}{\gamma}\beta\right)^{1/2}$$



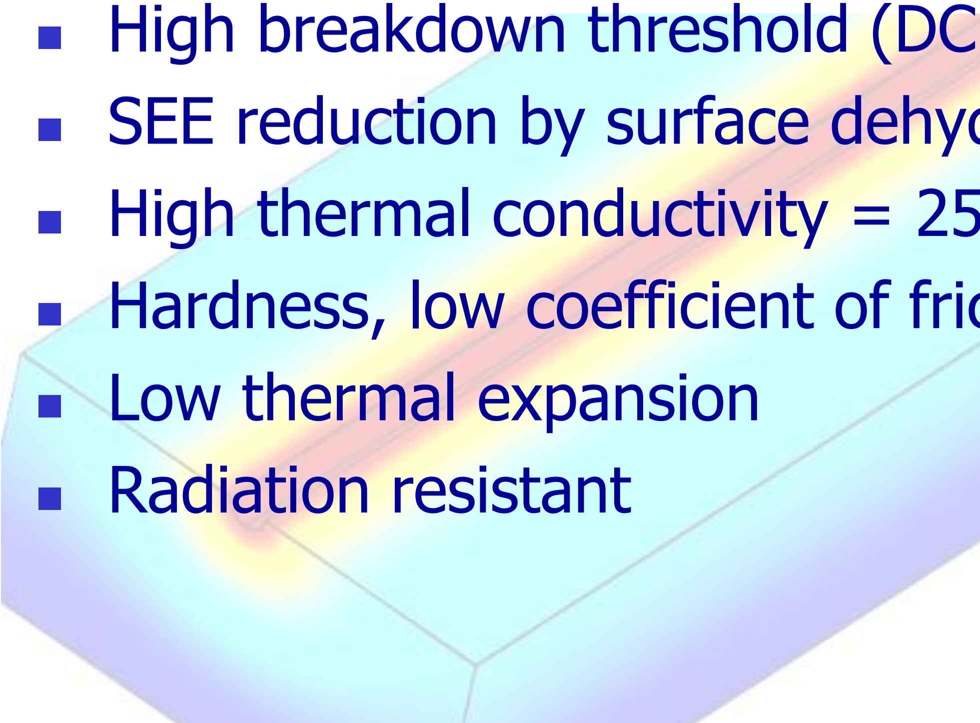
- Acceleration:
  - Collinear acceleration
  - Two-beam acceleration (CLIC-type)
  - Externally driven
- Structure:
  - Type of ceramics: loss, multipactor, thermal management, fabrication
  - Power extraction
  - Coupling schemes
  - Tuning
  - HOM suppression
- Beam:
  - Phase space manipulation
  - Bunch trains
  - Beam shaping for transformer ratio
  - Beam transport and BBU studies

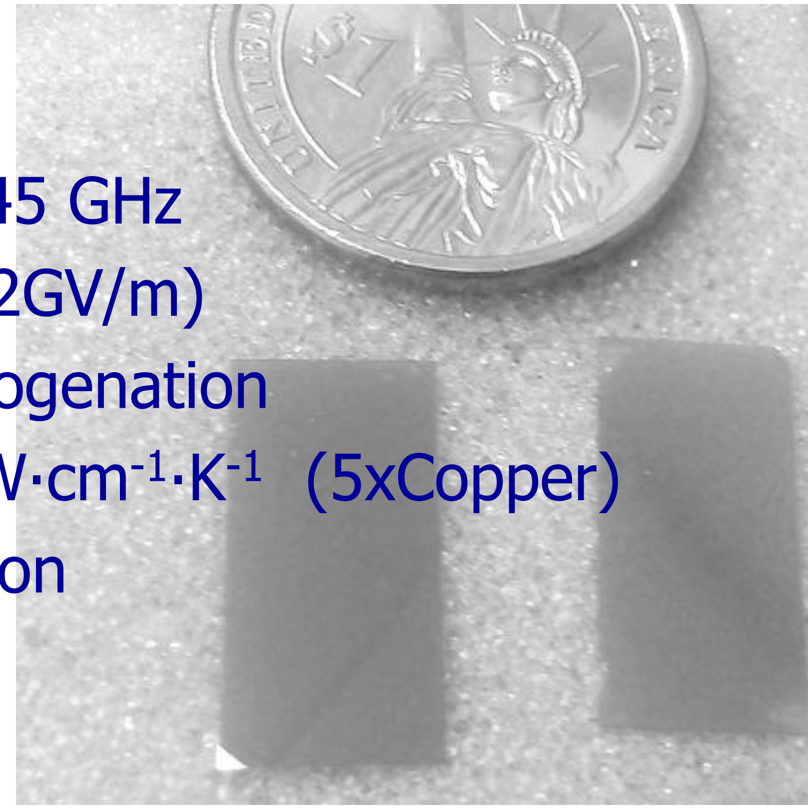
Our work across the spectrum and applications



Diamond

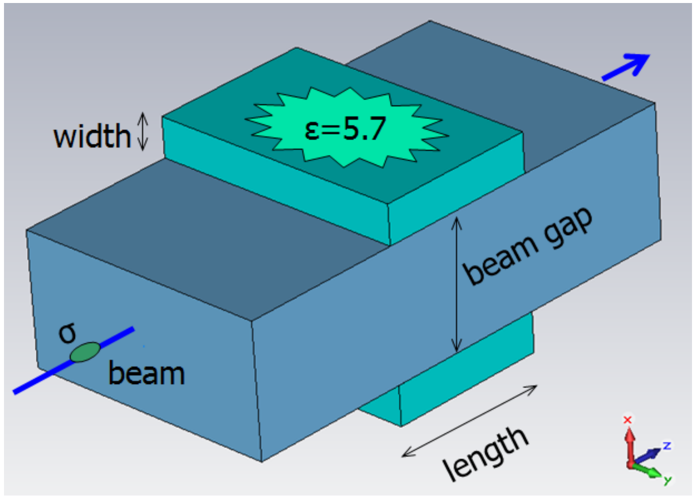
- $\varepsilon = 5.7$; $\tan \delta < 5 \cdot 10^{-5}$ at 30 - 145 GHz
- High breakdown threshold (DC~2GV/m)
- SEE reduction by surface dehydrogenation
- High thermal conductivity = 25 $W \cdot cm^{-1} \cdot K^{-1}$ (5xCopper)
- Hardness, low coefficient of friction
- Low thermal expansion
- Radiation resistant



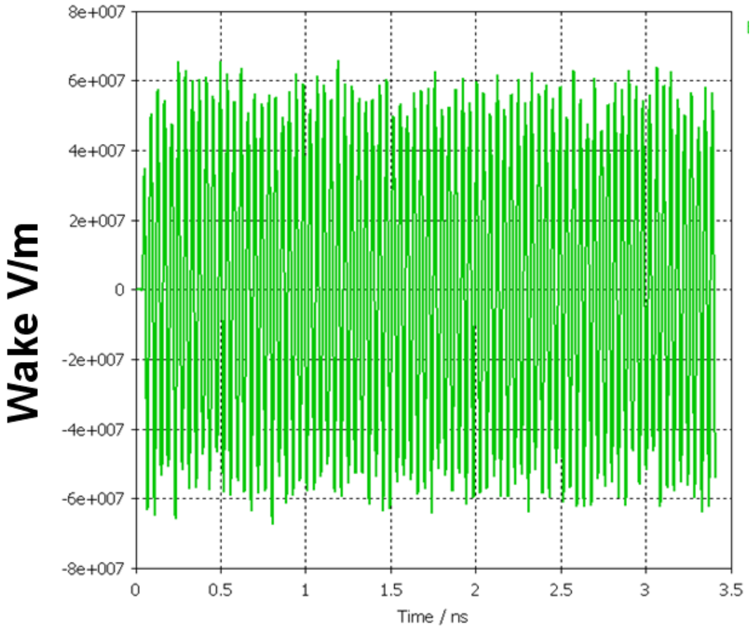


High Grad. Breakdown Study of A Diamond Slab Structure @ ANL/ AWA

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



50MV/m per 50 nC beam

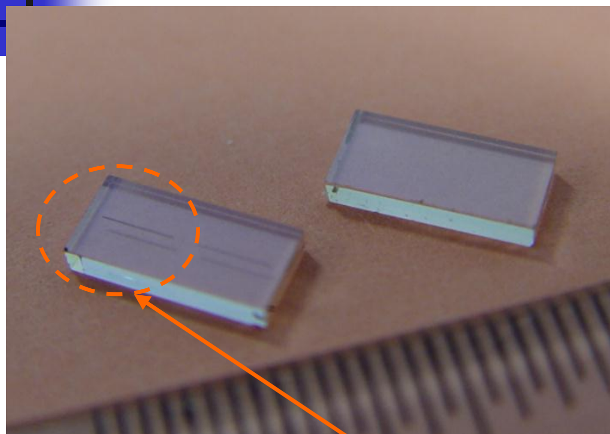


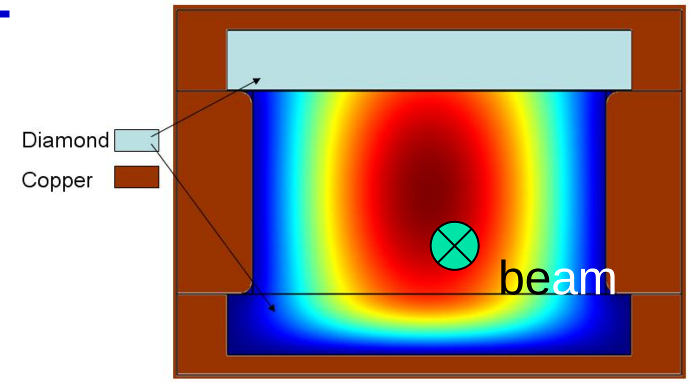
Bunch length	**2~2.5 mm**
Beam gap	**4.0 mm**
D thickness	**1.2 mm**
width	**8 mm**
length	**5.0 mm**

***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 (→decay time τ~35ns)

Field Enhancement in the scratch

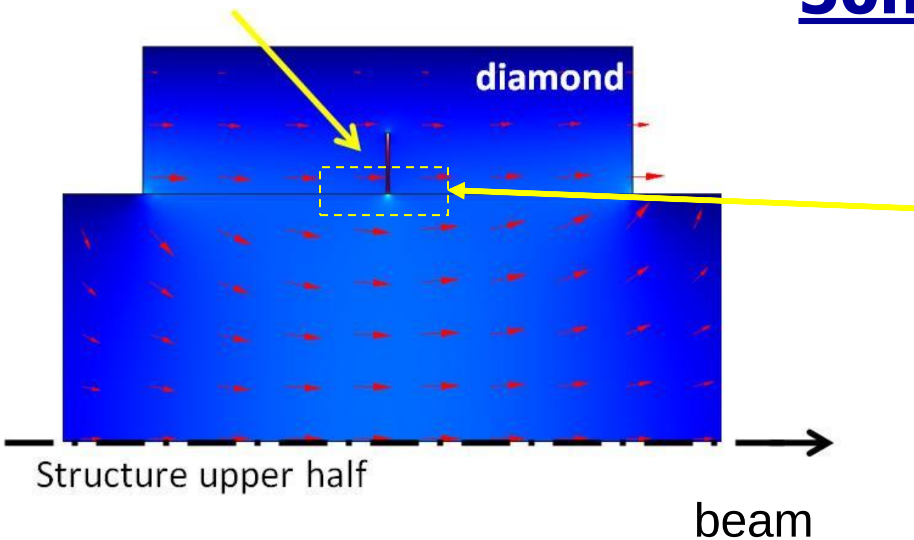


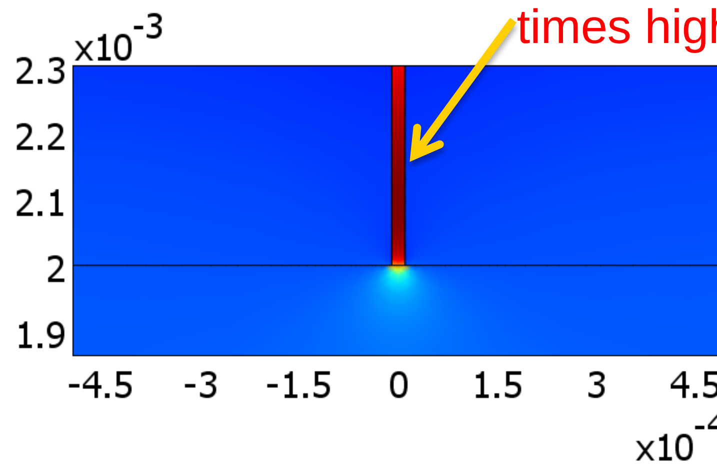


Avoiding hot spots on diamond holder

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

50nC → 250 MV/m



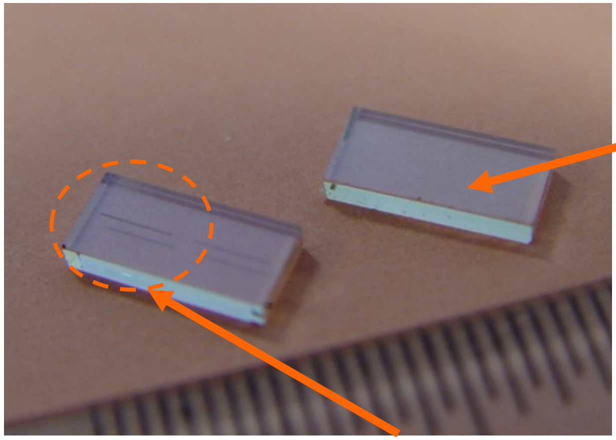


Diamond test at the AWA

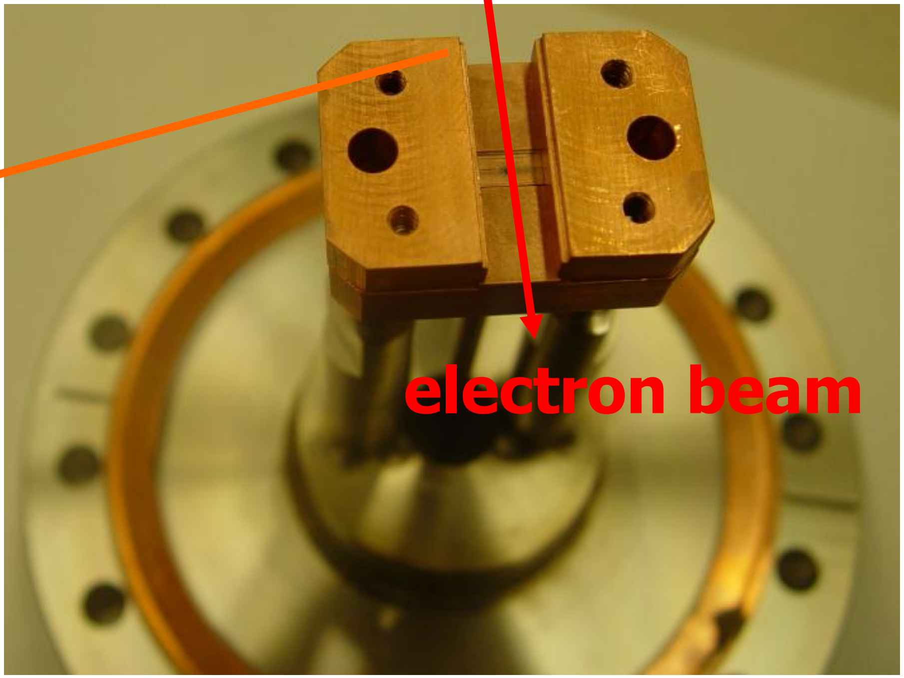
Frequency	**24.81 GHz**
Gradient (AWA 70 nC)	**60 MV/m**
Beam gap	**4 mm**
Diamond thickness	**1.2 mm**
Structure width	**8 mm**
Diamond length	**4 mm**
Dielectric constant	**5.7; tan(δ) = 10^{-4}**
Q, quality factor	**2800, τ ~ 35ns**
r/Q	**11.4 kΩ/m**

Single crystal CVD diamond (E6)
Groove: 20um (wide) x 200um (deep)
Field enhancement ~ ε·E ≈ **300 MV/m**
AWA transported 72nC through the structure

Upper half of the diamond resonator

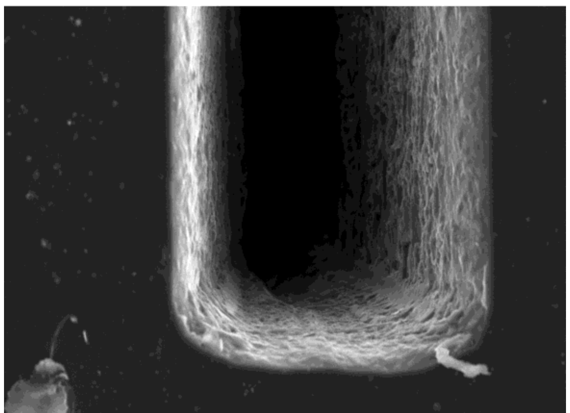


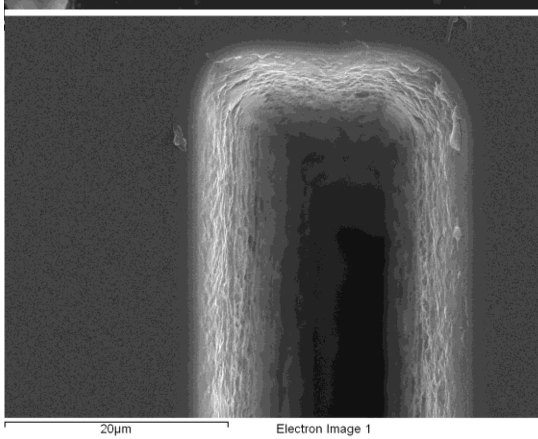
Diamonds (E6) ...**with a groove**

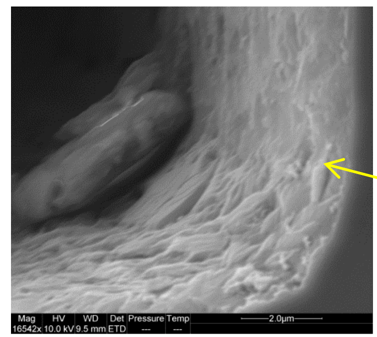


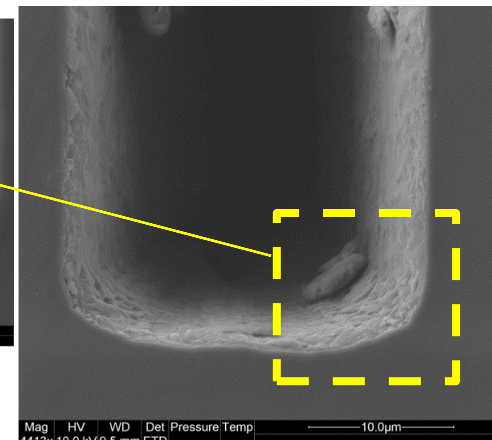
High Gradient Beam Test

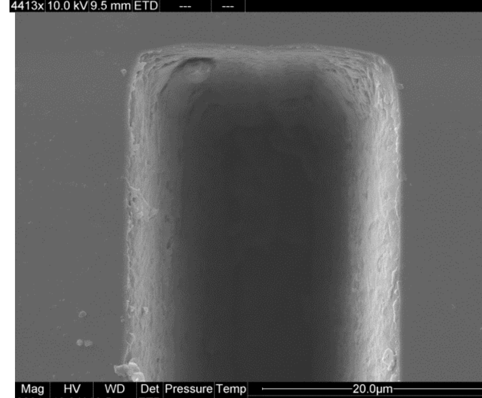
- 72nC (σ_z=2.5mm) went through which is *eqv*. to **<u>~300 MV/m</u>** gradient on axis for decay time **<u>τ ~ 35ns</u>**.
- Preliminary examination shows **No** evidence of breakdowns during the beam test. More examinations or additional test will be carried out.







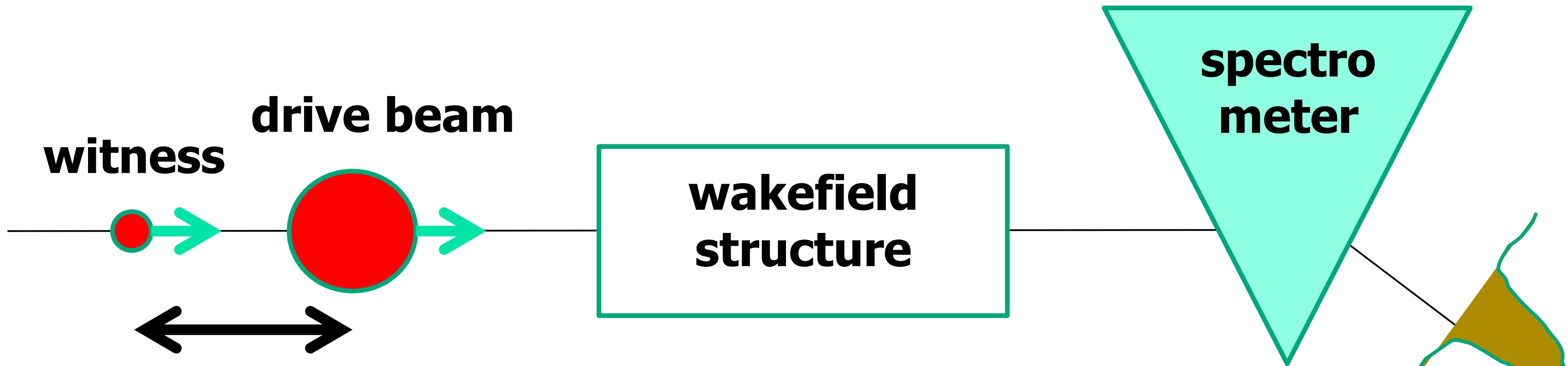




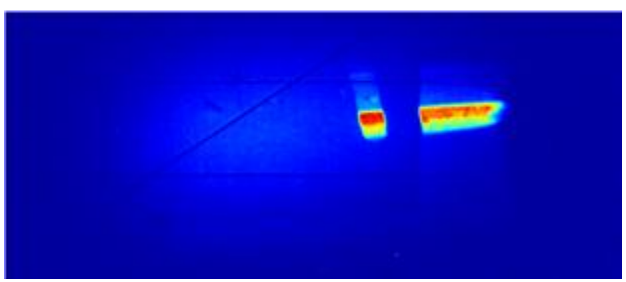
before after

SEM: Sergey Antipov, Euclid and Sergey Baryshev, MSD ANL

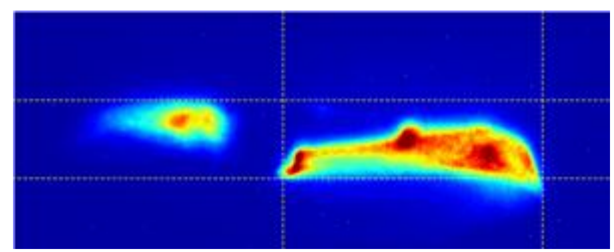
Wakefield Mapping



Change in D-W spacing → energy gain/loss of a witness

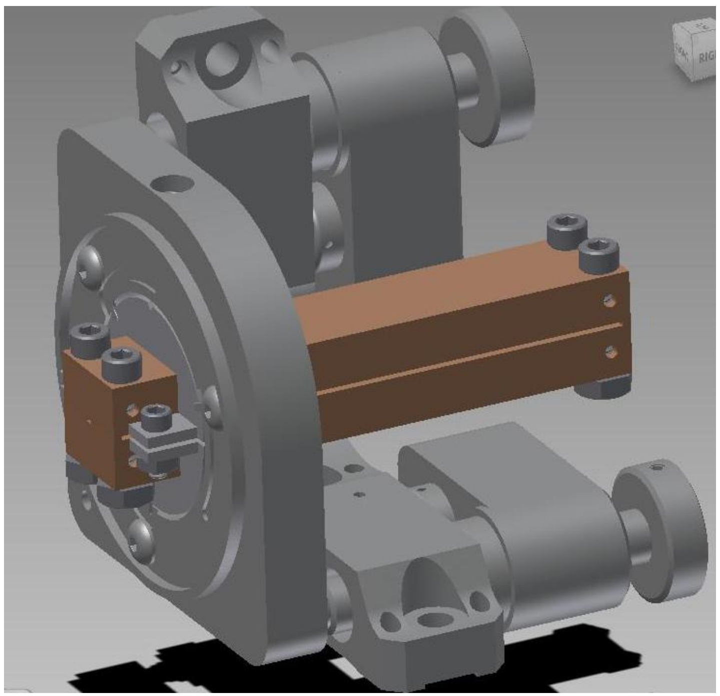


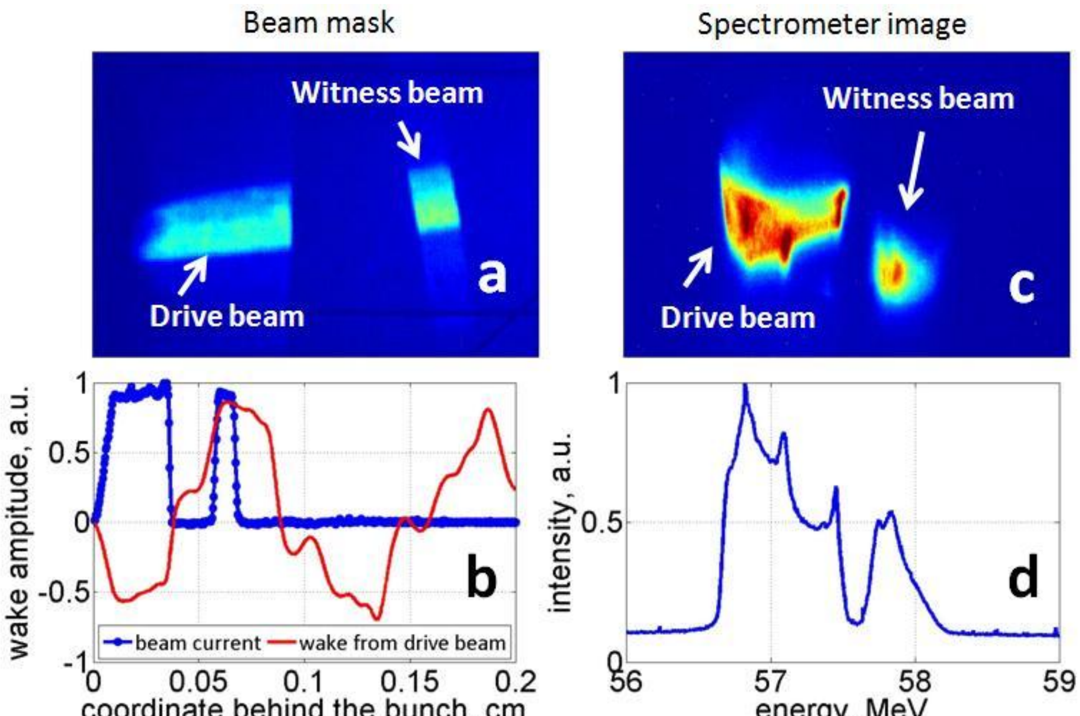
Experimental drive + witness visualization



Spectrometer measurement

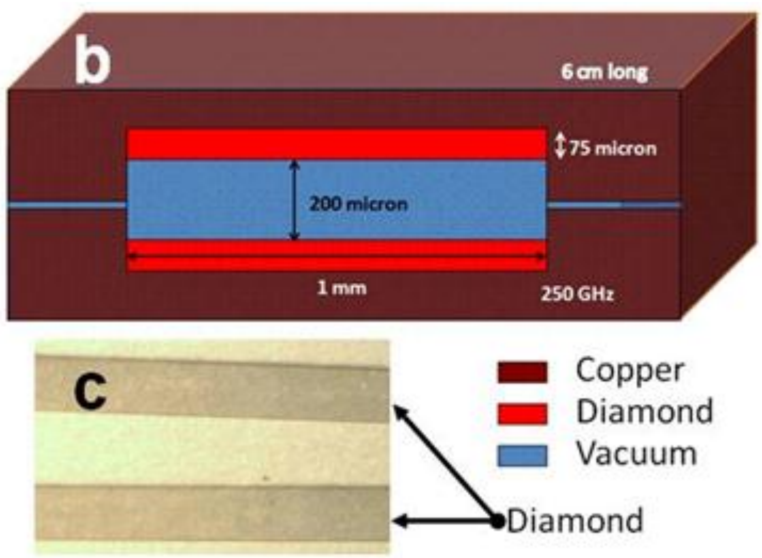
Experiment at ATF: Wakefields and the Structure

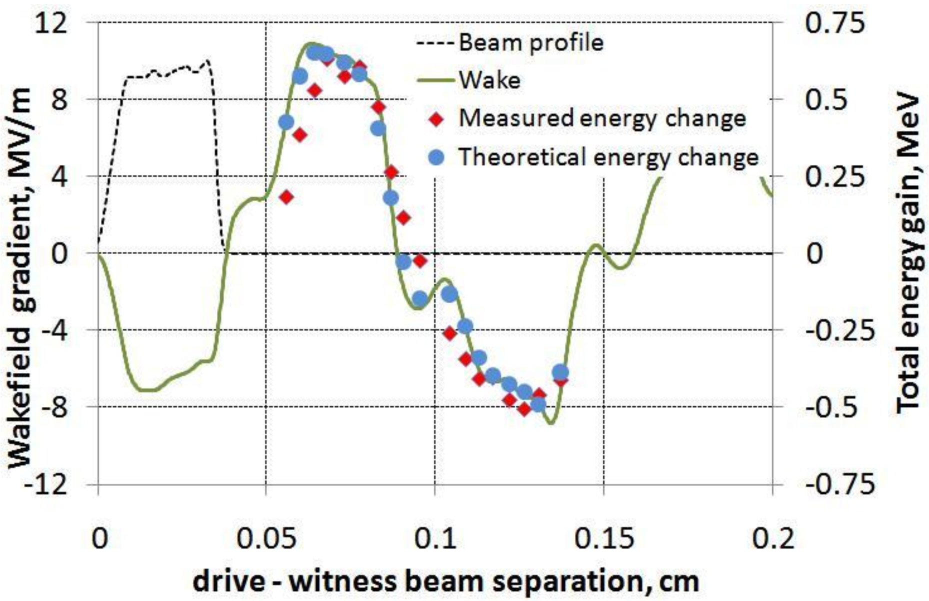




S. Antipov et. al. Appl. Phys. Lett. 100, 132910 (2012)

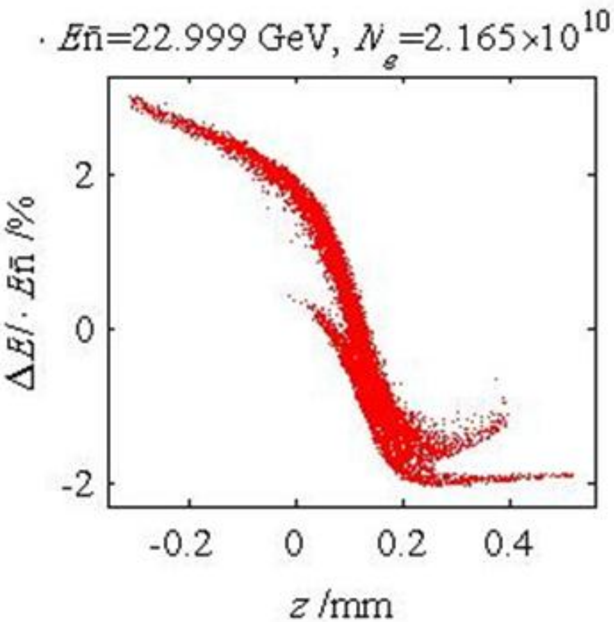
Wakefield Mapping of a Diamond Slab Structure at BNL/ ATF

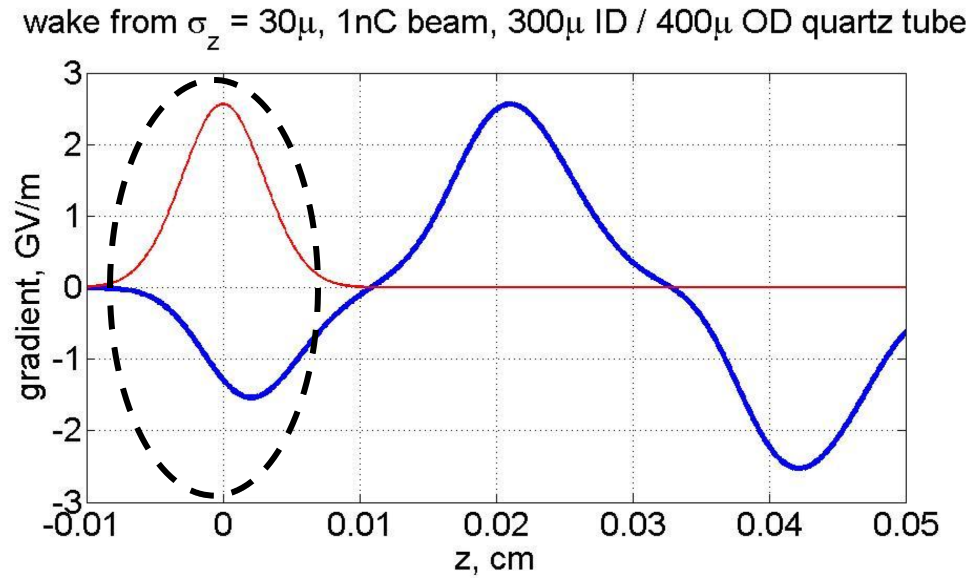




- 1st wakefield mapping experiment in THz regime (June 2011).
- 1st wakefield acceleration observed in THz regime.
- S. Antipov, *et al, App. Phy. Lett. March* 2012.

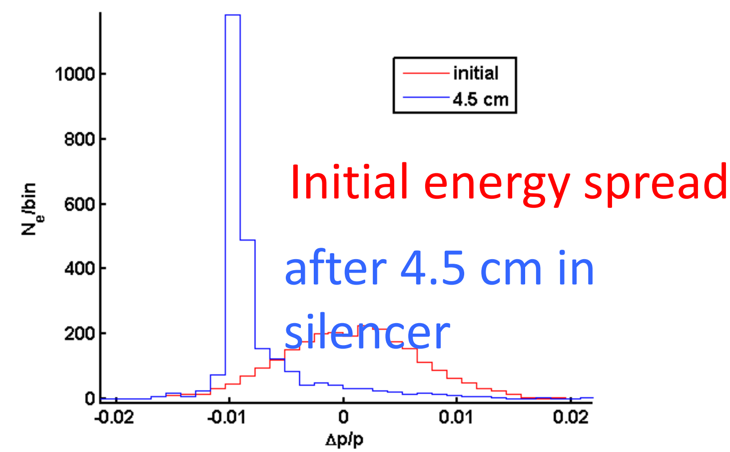
Energy chirp compensation





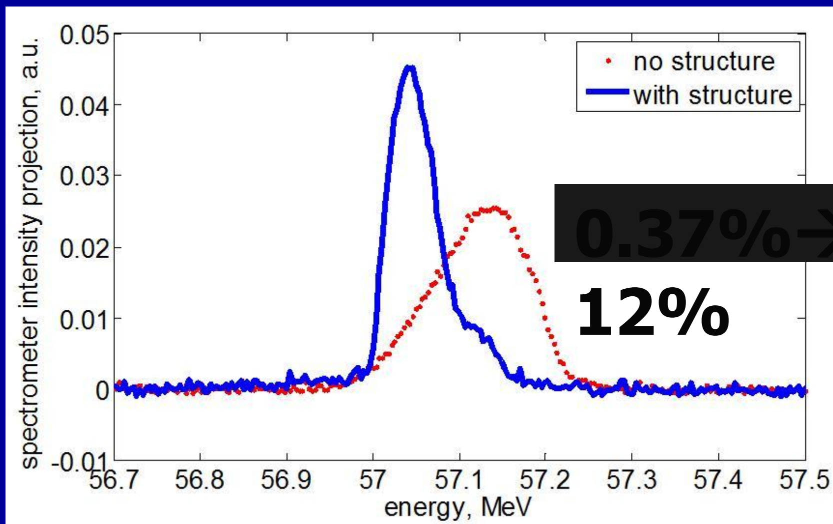
FACET beam

From M. Hogan, J. England (SLAC)



- Passive device (beam self-action)
- Can be tunable
- Ex. FACET 5% spread → 0.75% using a 5cm device

Energy chirp correction demonstrated ATF



[redacted]
12%

Limited by spectrometer resolution

Beam transmiss

SS housing tubes

Quartz tubes (ε = 3.8)

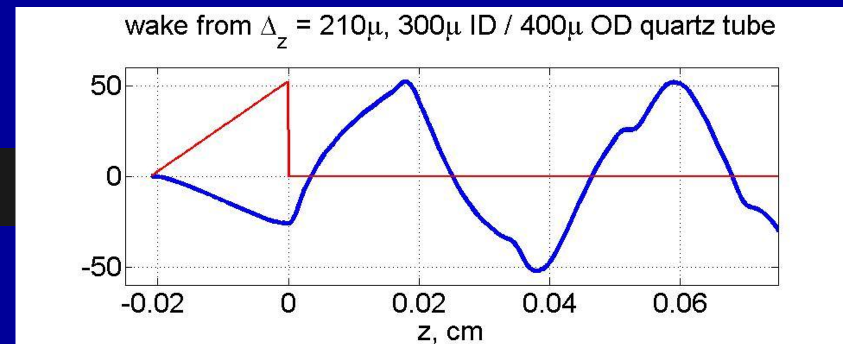
(Gold sputtered)

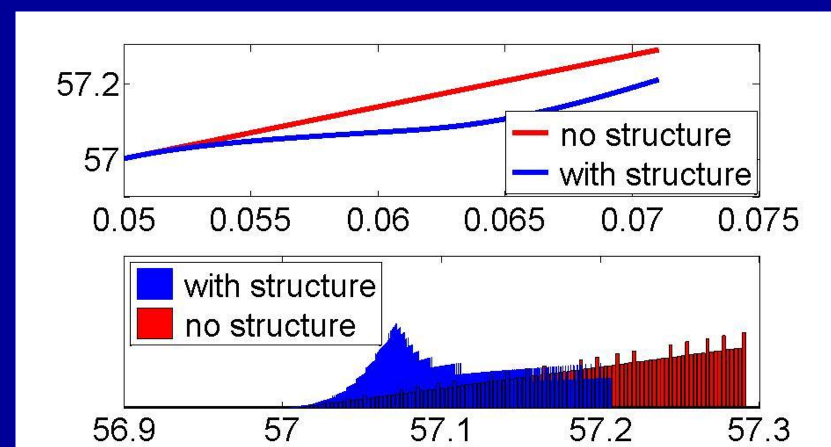
Sizes (ID / OD):

1", 200 x 330 μ

1", 300 x 400 μ

2", 400 x 550 μ





Linear chirp correction / energy

S. Antipov et al. Phys. Rev. Lett. 108, 144801 (2012)

Conclusion

- Experimentally demonstrated direct wakefield acceleration using diamond loaded 0.25 THz planar structure. A THz diamond based structures tested at BNL/ATF showed no evidence of poly-crystalline structure deformation

- Diamond samples have been tested at Ka-band with 300 MV/m wakefield 35 ns pulses - no evidence of polycrystalline structure deformation