Table Top Narrow Bandwidth Tunable THz source

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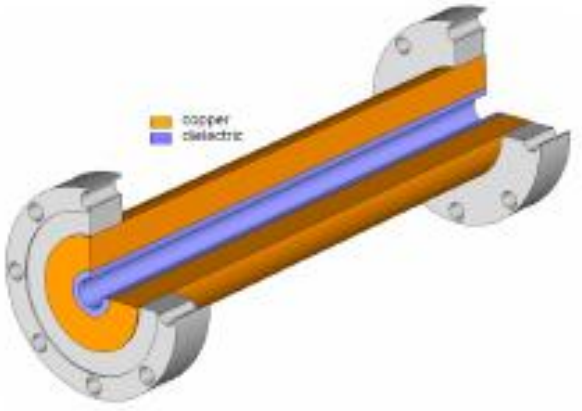
Workshop on Terahertz Sources for Time Resolved Studies of Matter, 7/31/2012

Wakefield acceleration and DLA technology

- Personal experience: wakefield studies at Argonne Wakefield Accelerator:
  - ~150nC / 8ps bunch (world record?)
  - 100 MV/m gradient demonstrated in Dielectric Loaded Accel.
  - Power extraction studies 16ns,1MW & 6ns, 30MW 26GHz rf pulse produced; Working toward 20ns 150MW
- Wakefield: charge↑, bunch length↓, emittance↓ **structure aperture↓ → arrive to THz**
- Dielectric loaded structures:

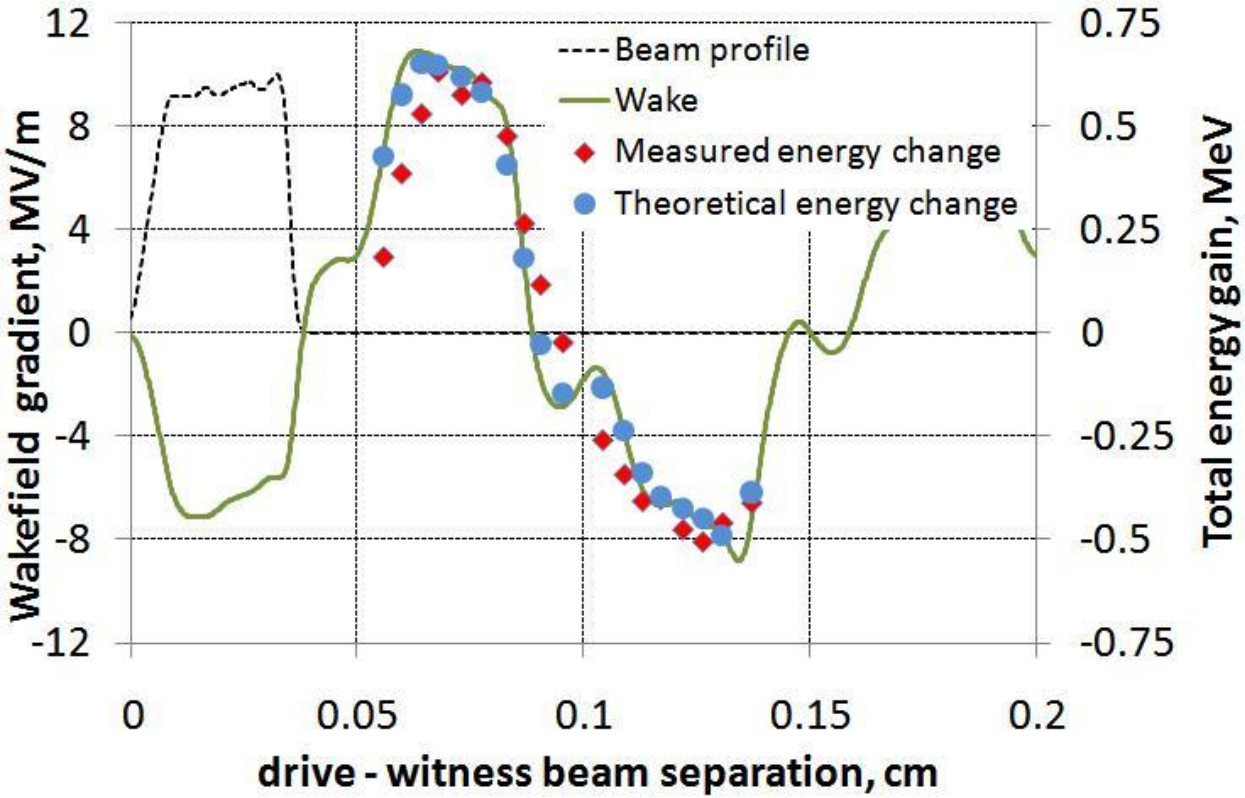
simplicity, scalability (THz),

breakdown strength



Wakefield mapping in THz structure

Pump – probe experiment analogy… 0.25 THz, 1 λ sampled
Energy gain of the probe beam vs time delay



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

FFTB

- FFTB (SLAC)
  - Fused silica tube, metallized OD=324um, ID = 100um, L=1cm
  - SLAC beam σ_z = 10 – 100um, σ_r = 10um
  - 16 GV/m maximum accelerating field achieved
  - Metallization evaporated due to ohmic heating
  - dielectric brakedown observed (maximum field on dielectric surface ~ 27 GV/m
  - In fact a narrow band (long pulse) high peak power THz: **0.5THz, 3GW peak power, 2.85mJ, 2.3% BW ~ 88ps***

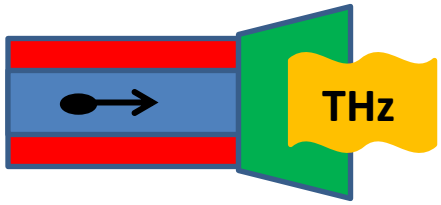
Thompson et al
PRL 100, 214801 (2008)

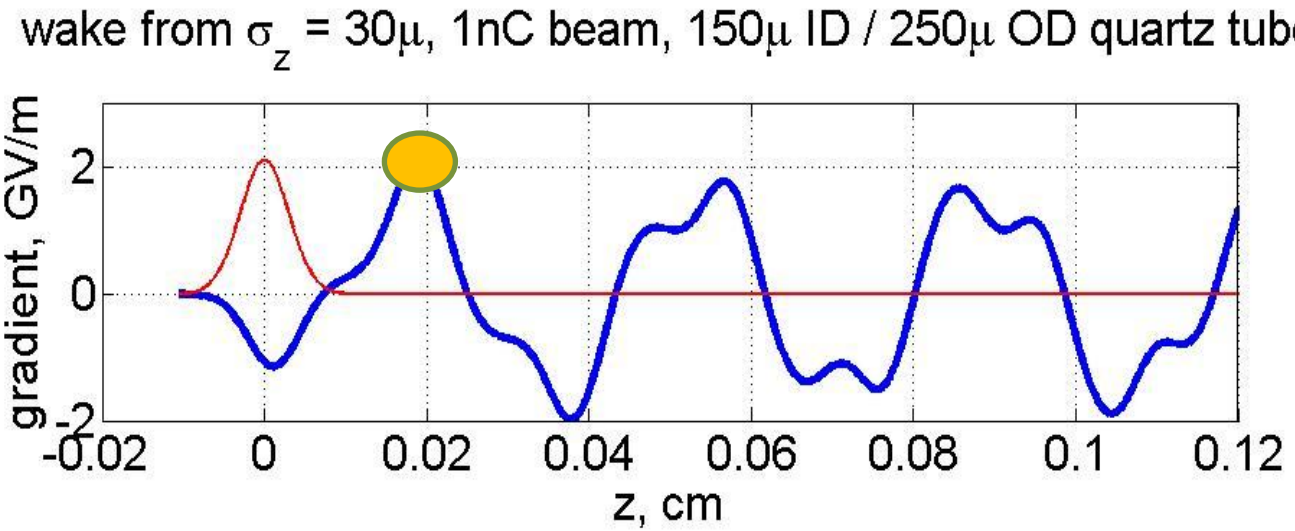
*Calculations (and errors) by Antipov

- FFTB →

FACET (2012)

THz numbers @ FACET E201/205





$BBU_{10\%}$ > 0.1m

ΔE ≈ 0.9 GeV

3nC/σ_z=30μ FACET beam

v_g=30%, 1.5cm long structure → 1% bandwidth

→ 0.84 THz / 0.78 GW (peak power)

→ 0.92mJ per pulse

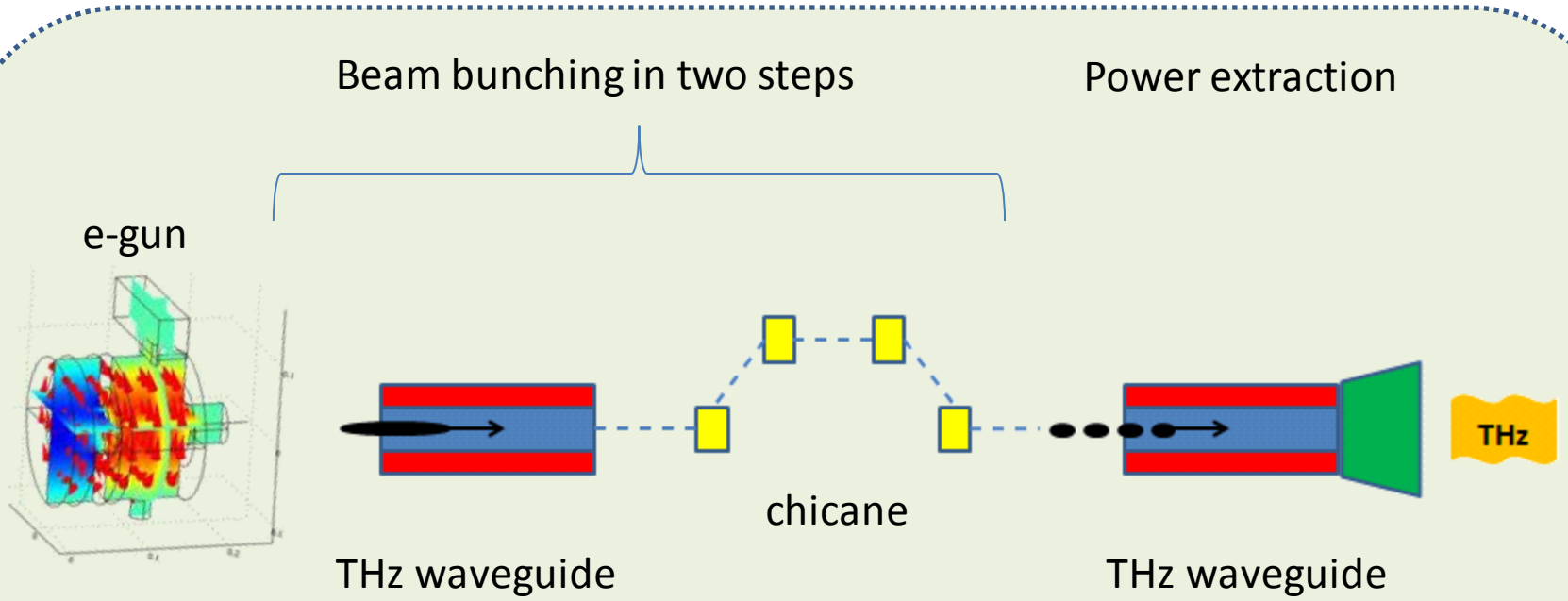
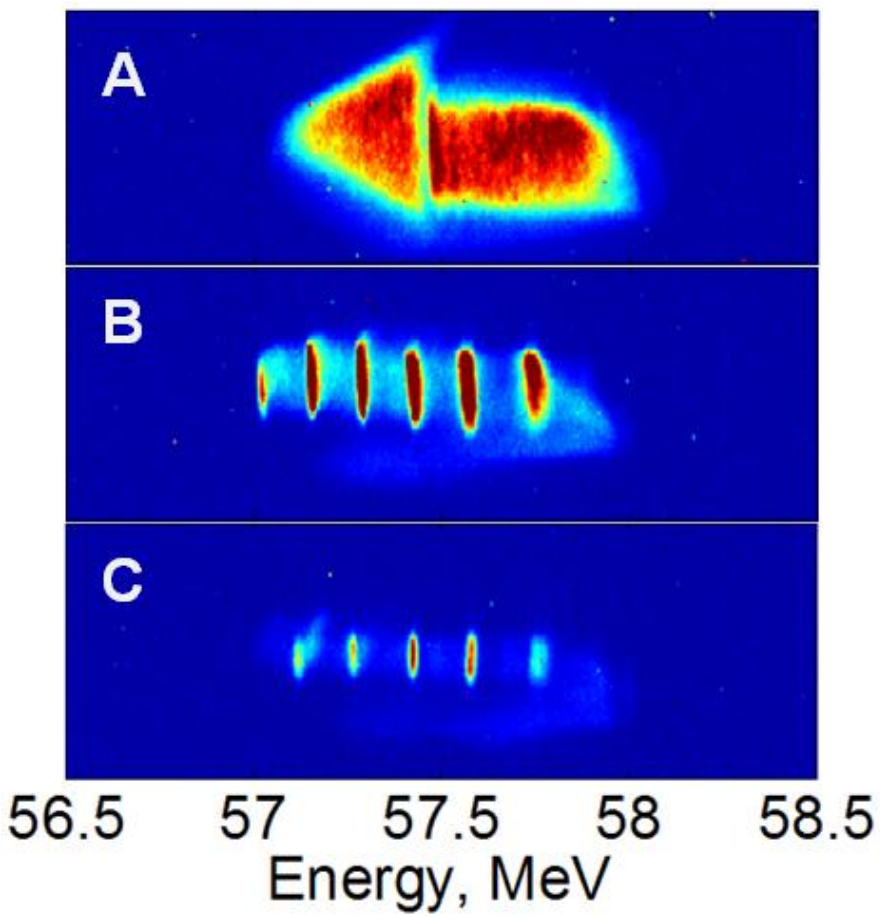
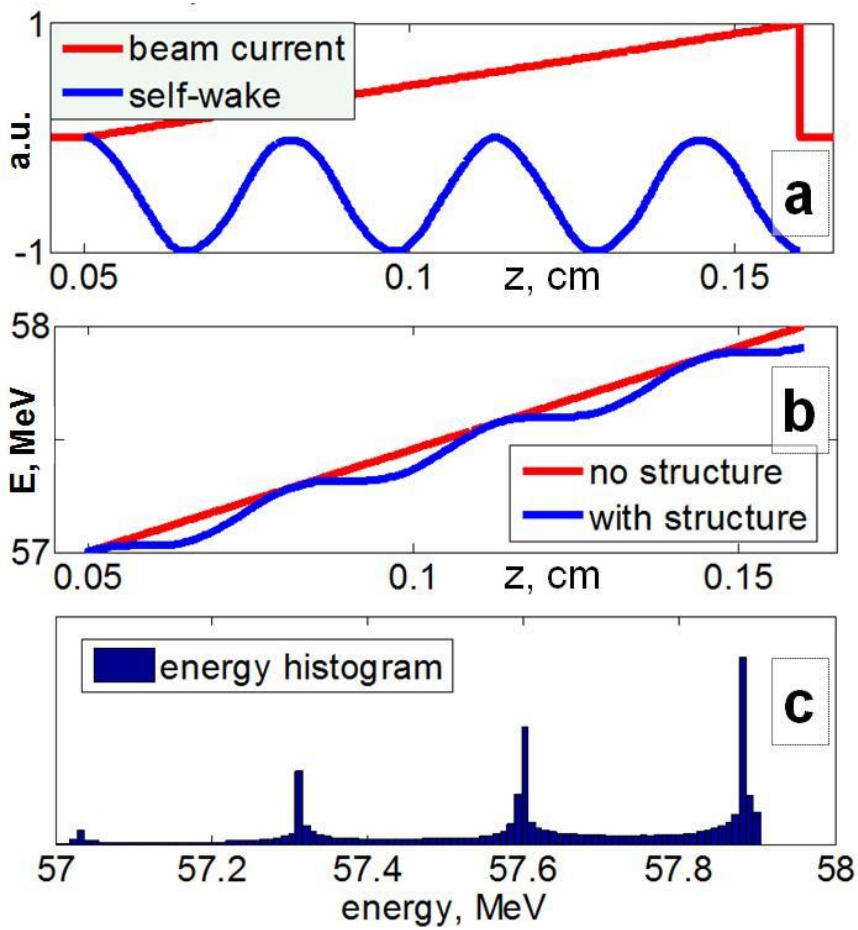


TABLE TOP BEAM DRIVEN THz SOURCE

… or amplifier

Stage I demonstrated at the ATF (BNL)

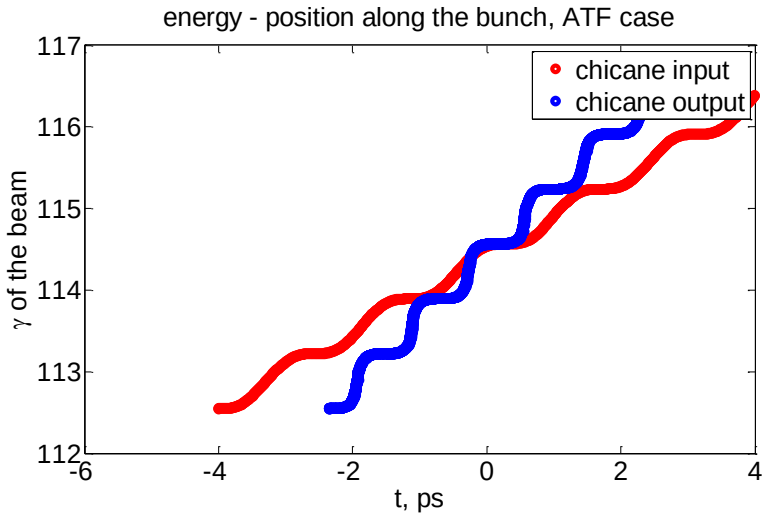


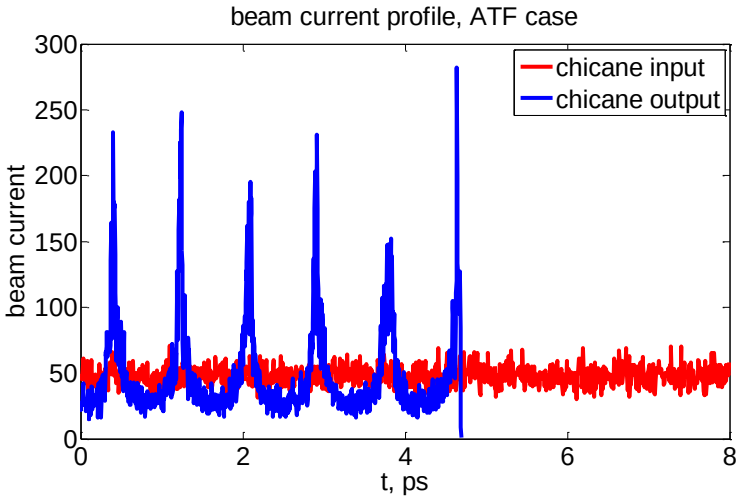


***Also demonstrated: energy chirp compensation**

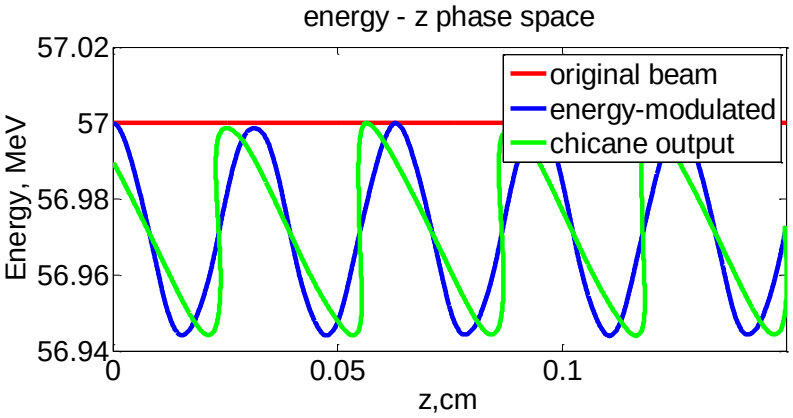
S. Antipov, et. al. Phys. Rev. Lett. 108, 144801 (2012)

Stage II: energy → density modulation



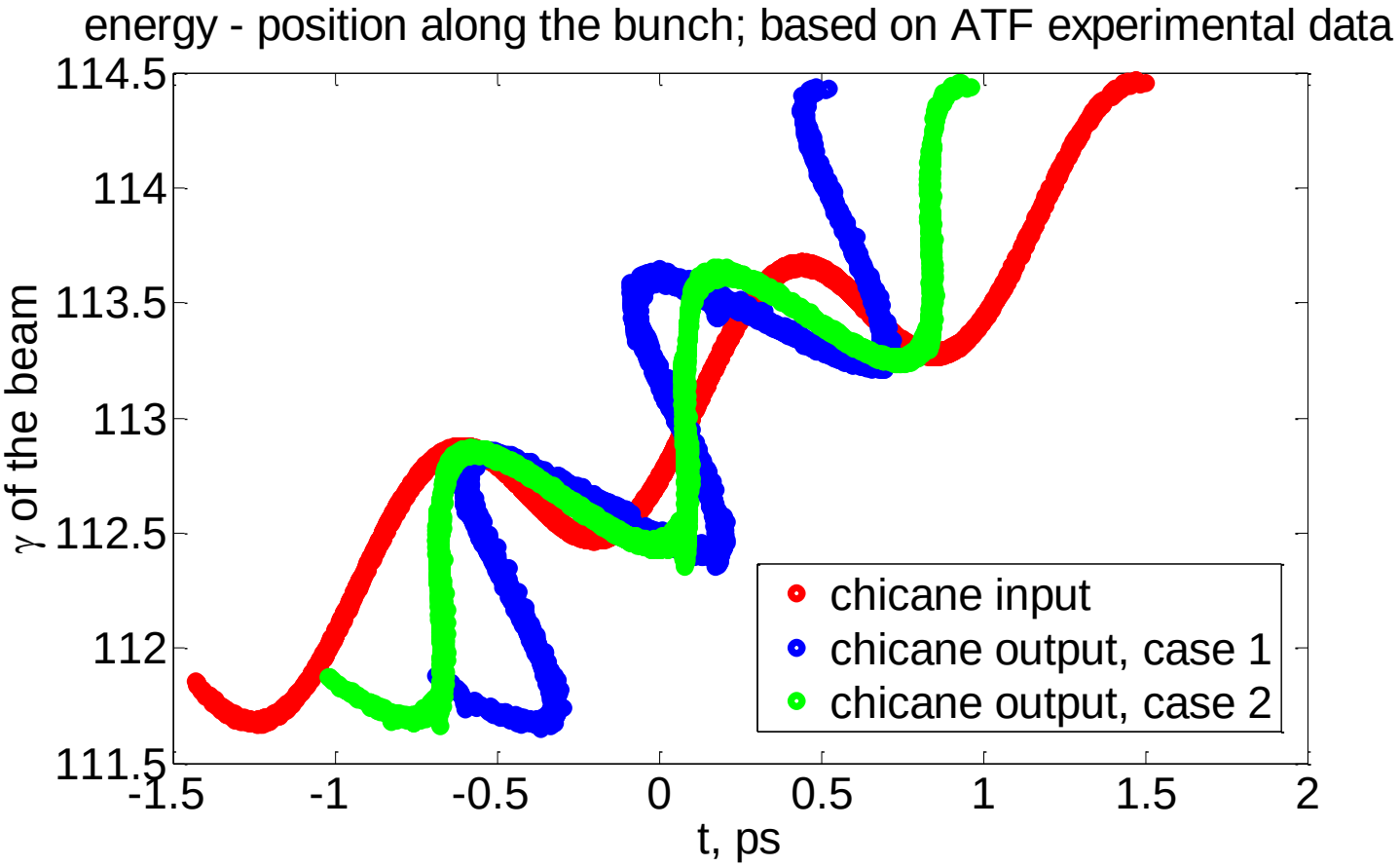


***no energy chirp:**



- Chirp is convenient for experiment
- Not required; Beam dynamics issues.
- No chirp → frequency of bunch train equals to frequency of the wakefield structure
- Chirp allows to increase the bunch train frequency for a given wakefield modulation structure

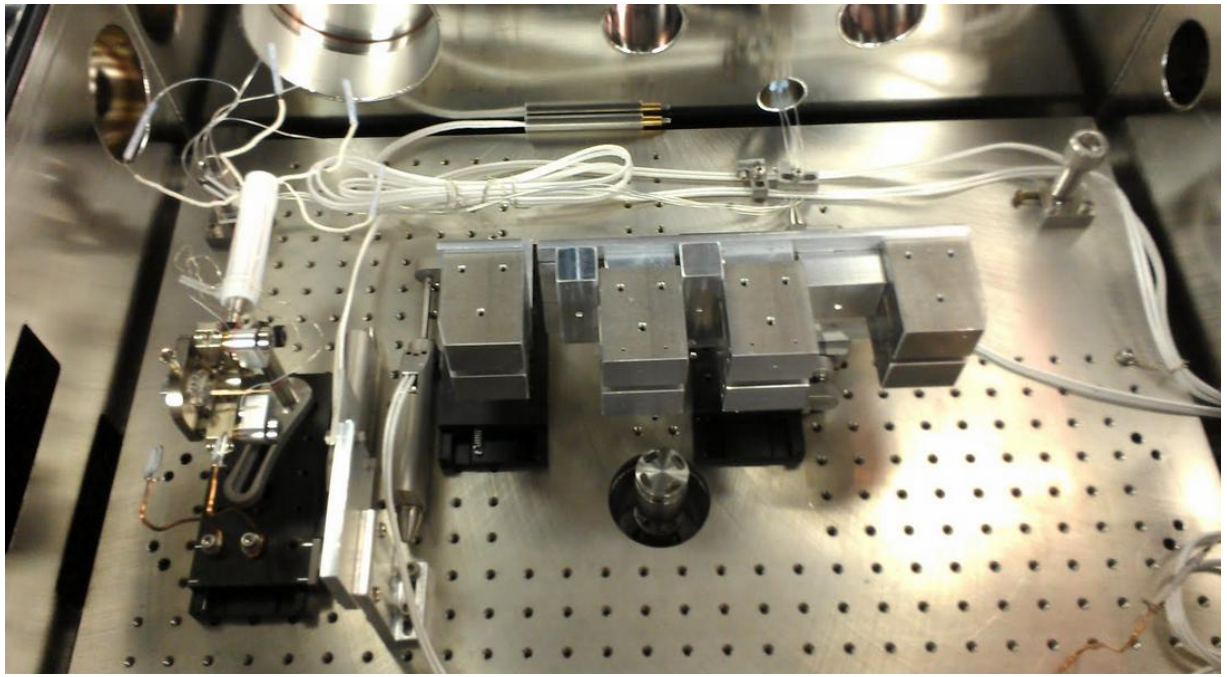
Adjustment by chicane



Errors in stage I (beam energy over/under modulated) can be corrected by chicane in stage II

Stage II: demonstrated at ATF (BNL)

Rectangular
1.7mm beam

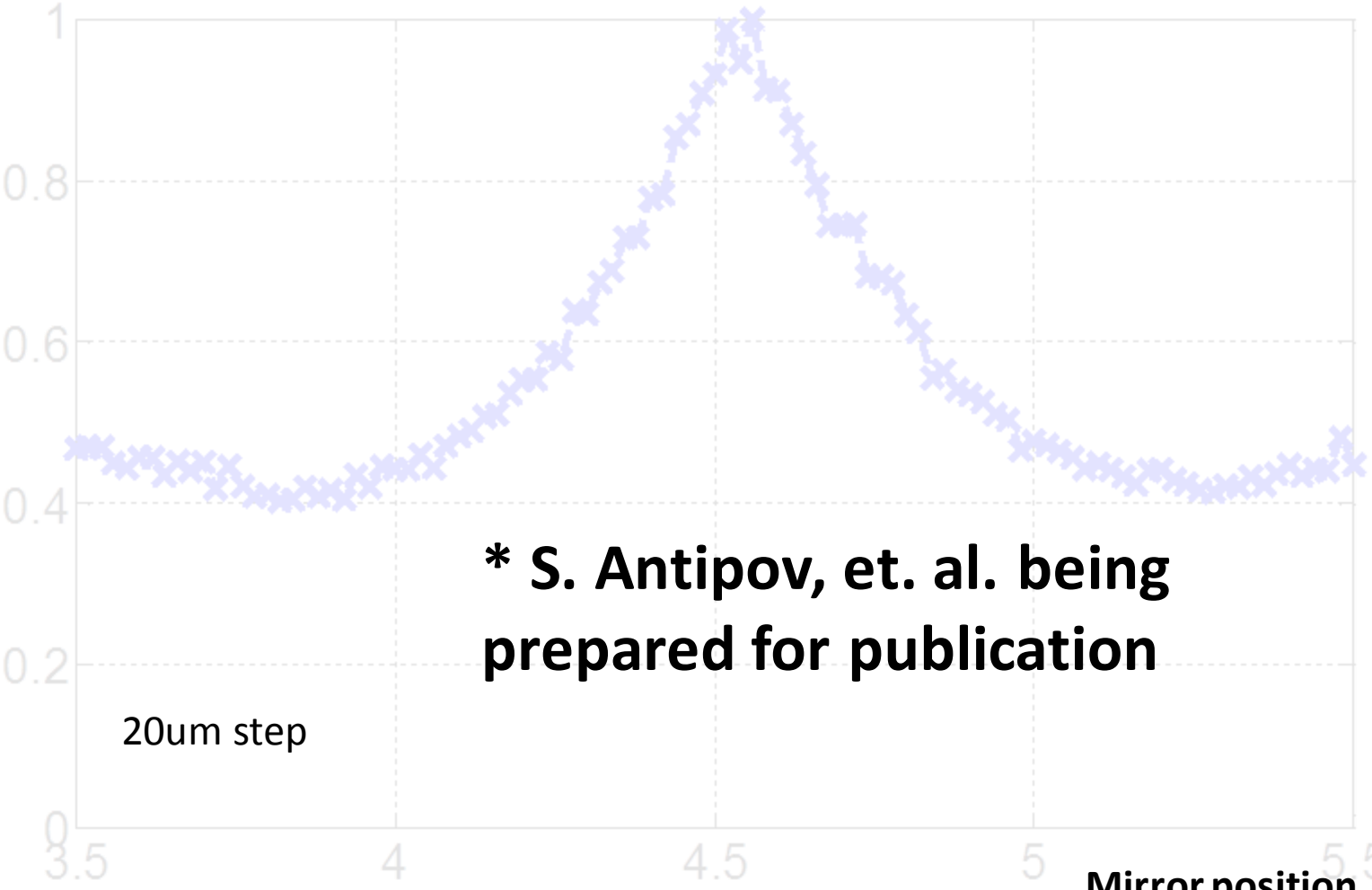


To CTR
interferometry

- Compact (regular 1” optical breadboard), permanent magnet chicane (motorized)
- 2” long 600um aperture Kapton tube (thin wall), metallized on the outside

*** S. Antipov, et. al. being prepared for publication**

Measured interferogram: no chicane

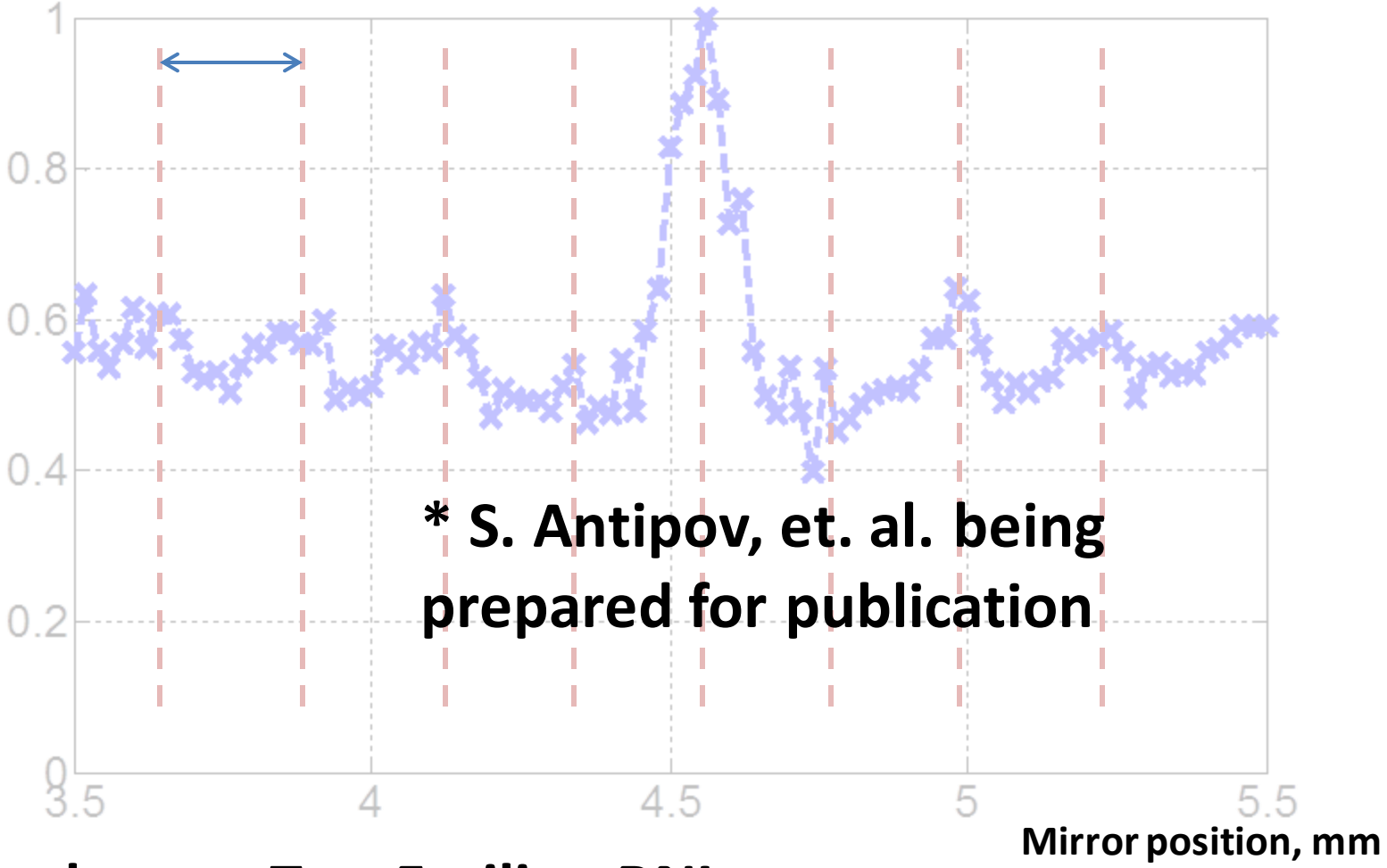


*** S. Antipov, et. al. being prepared for publication**

@ Accelerator Test Facility, BNL

Measured CTR interferogram: with chicane

~215um → spatial modulation periodicity is ~430um → 700 GHz



*** S. Antipov, et. al. being prepared for publication**

@ Accelerator Test Facility, BNL

Table top beam-based THz source

BNL, ATF: S. Antipov, C. Jing et. al.
Phys. Rev. Lett. 108, 144801 (2012)

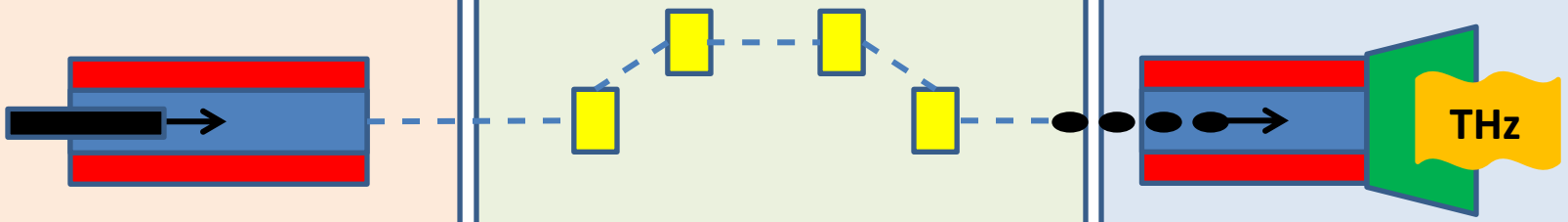
Energy modulation via self-wakefield

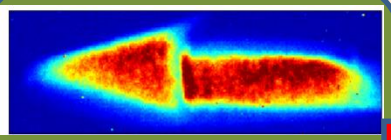
SLAC, NLCTA: D. Xiang et. al.
Phys. Rev. Lett. 108, 024802 (2012)
BNL, ATF: S. Antipov, et al. to be published

Chicane energy modulation conversion to bunch train

BNL, ATF: G. Andonian et. al.
Appl. Phys. Lett. 98, 202901 (2011)

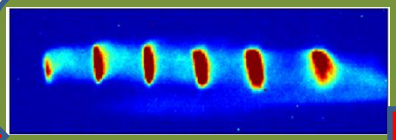
THz radiation wakefield structure





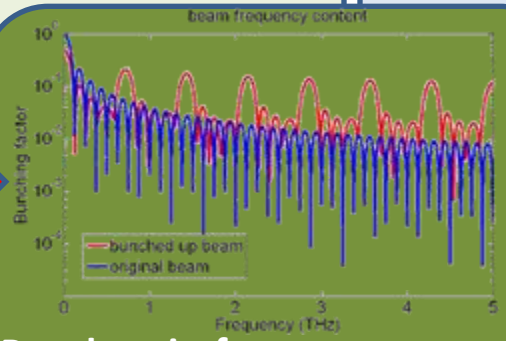
Measured beam spectrum

Energy chirped rectangular beam



Measured beam spectrum

Energy modulated rectangular beam

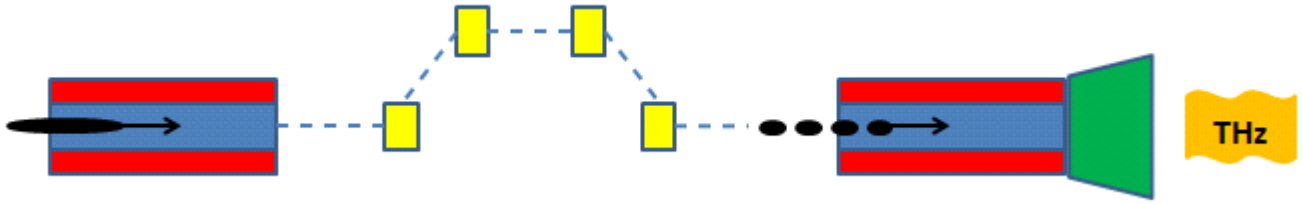


Bunch train frequency content

Tunable 100% source:
Range: 0.3-1.5 THz
Pulse bandwidth: 1%
Energy in pulse: ~ mJ

Flexible: each step has a tuning range

Stage III: power extraction in numbers



extraction structure	Beam @ the entrance	THz Radiation @ the exit
0.3mm / 0.4mm Quartz 3cm long	(ATF beam) **2.4mm, 0.8nC** rectangular, bunched	**6 MW peak, 0.7THz, 161ps pulse, 0.9%BW, 1.4mJ per pulse**
1mm / 1.2mm Quartz 10cm long	(AWA beam) **6.3mm, 10nC** rectangular, bunched	**0.5 GW peak, 0.3THz, 320ps pulse, 1%BW, 155mJ per pulse**