A Quasi-Optical Beam Position Monitor

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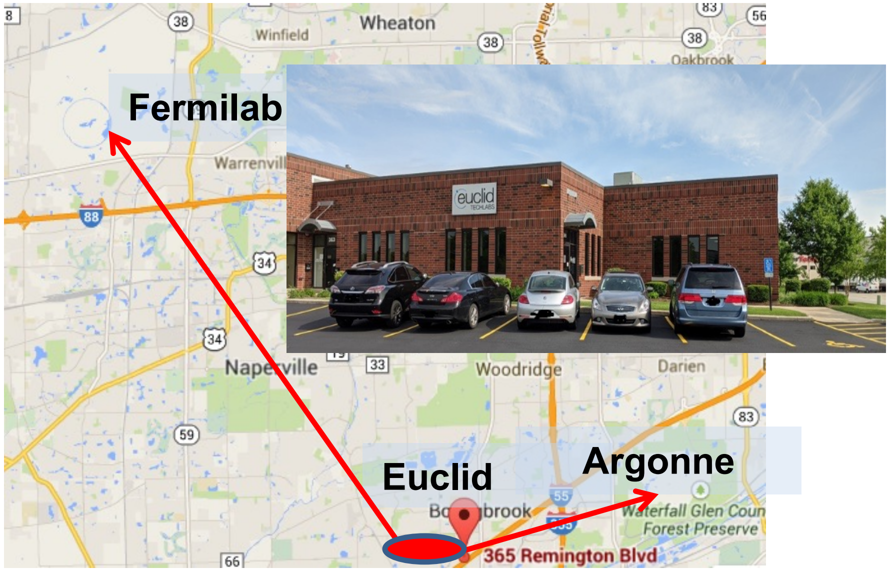
Euclid Techlabs/Euclid Beamlabs

Euclid Techlabs, LLC is a research and development company specializing in linear particle accelerators, ultrafast electron microscopy, and advanced material technologies. The company was formed in 2003. Euclid Beamlabs LLC, formed in the winter of 2014, is a sister (spin-off) company of Euclid Techlabs LLC, particularly to commercialize industrial accelerator and related advanced material technologies developed at Euclid Techlabs. Euclid has developed expertise and products in several innovative technologies: time-resolved ultra-fast electron microscopy; ultra-compact linear accelerators; electron guns with thermionic, field emission or photo-emission cathodes; fast tuners for SRF cavities; advanced dielectric materials; HPHT and CVD diamond growth and applications; thin-film for accelerator technologies; Present: 27 people research staff (researchers, engineers, technicians) and 5 administrative. 16 PhDs in accelerator physics and material science, 32 staff. 2 labs: Bolingbrook, IL (accelerator R&D lab) and Beltsville, MD (material science lab). Long term collaborations with National Labs and Institutes: ANL, Fermilab, BNL, Jlab, LBL, SLAC, LANL, NIST, NIU, IIT, etc.



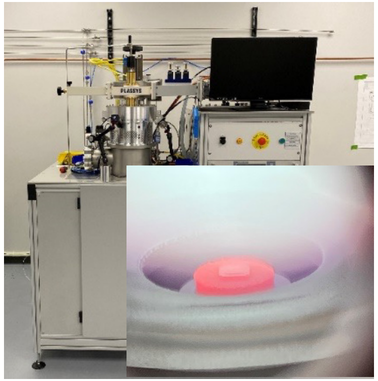
Products & Capabilities Snapshot

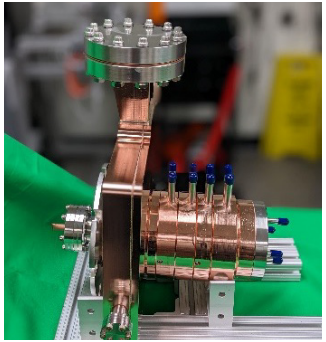
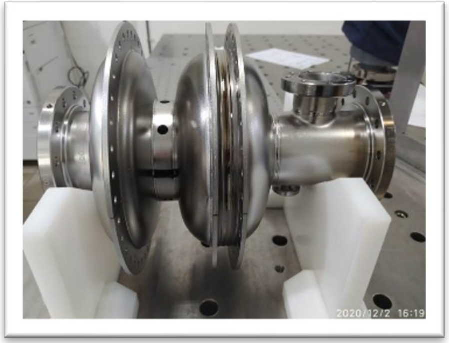
Products

- UltraFast Pulser (UFP™) for TEM
- Dislocation free diamond for Xray optics
- Compact X-Ray Source
- NCRF and SRF electron sources
- Low loss ceramics (linear and non-linear)
- LINAC
- RF window
- In flange BPM

Capabilities

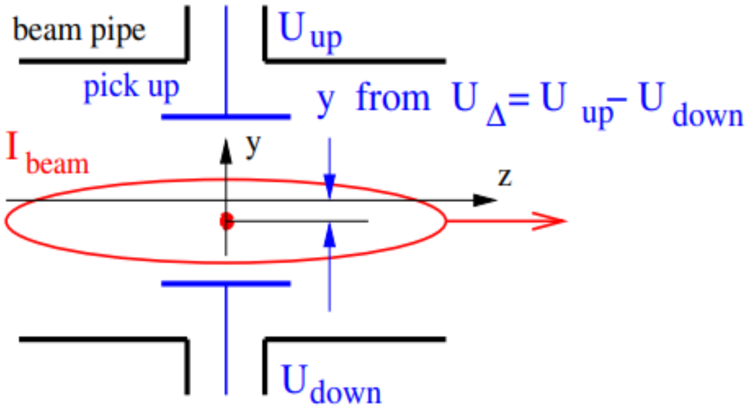
- Femtosecond Laser Ablation System
- Thin Film Deposition Lab
- EM Testing Lab
- Radiation Shielding/Testing Lab



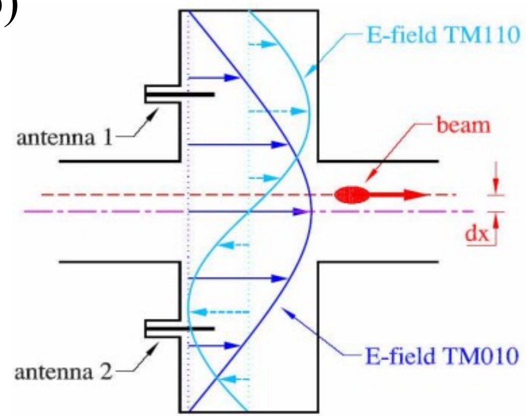



Motivation for Quasi-Optical BPMs (QBPMs)

(a)



(b)

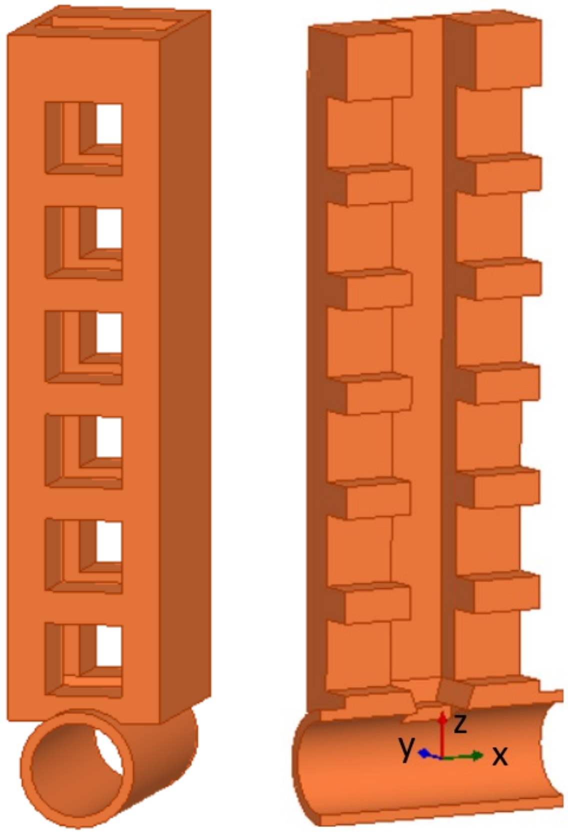


Classical button BPM based on proximity effect (a) and pillbox cavity BPM (b). [*P. Forck, et al. CERN Accelerator School 2009.*]

Femtosecond bunches produce petahertz spectra. For classical BPMs bunches become inevitably shorter than the length of the capacitor. In this case the capacitor must be considered as a broadband RF antenna, the BPM signal is noisy. These challenges can be approached by the excitation of resonator modes within a so-called cavity BPM.

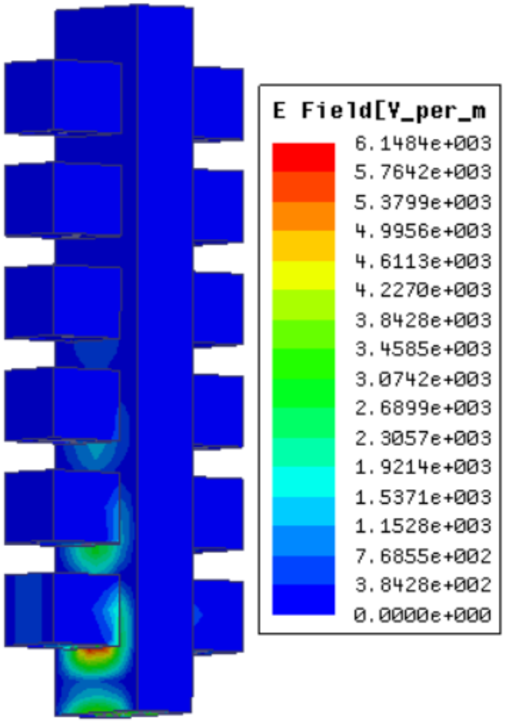
QBPM allows to excite a single mode in a very broad frequency band.

QBPM RF Design

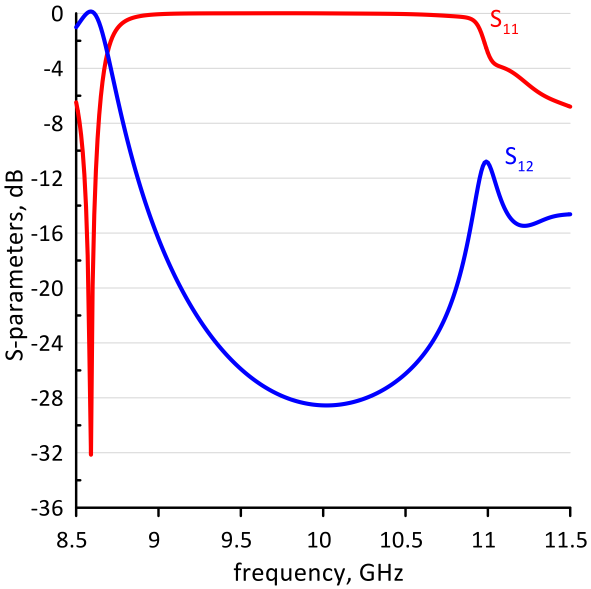


- We suggest using a pair of identical high-quality open resonators of the PBG type attached to opposite sides of the beam pipe.
- Each resonator consists of a periodically perforated rectangular cross-section waveguide (Bragg reflector).
- A proper resonator design can provide that only the lowest frequency mode can be excited. The frequency of this mode is cut off for the beam pipe. Bunches located closer to the coupling hole generate higher operating mode fields in the resonator compared with those bunches that move at a larger distance.

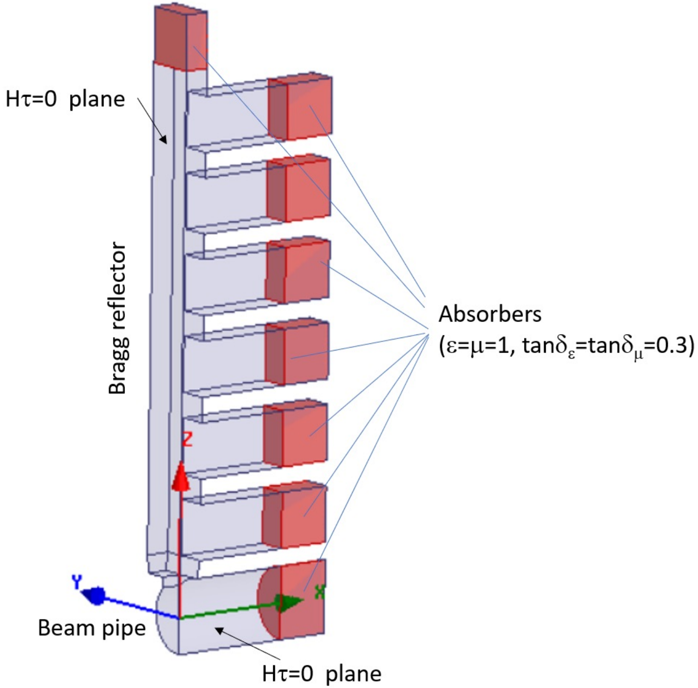
Bragg Reflector and HFSS Model for 10 GHz QBPM



E-field structure of Bragg reflector at 10 GHz.

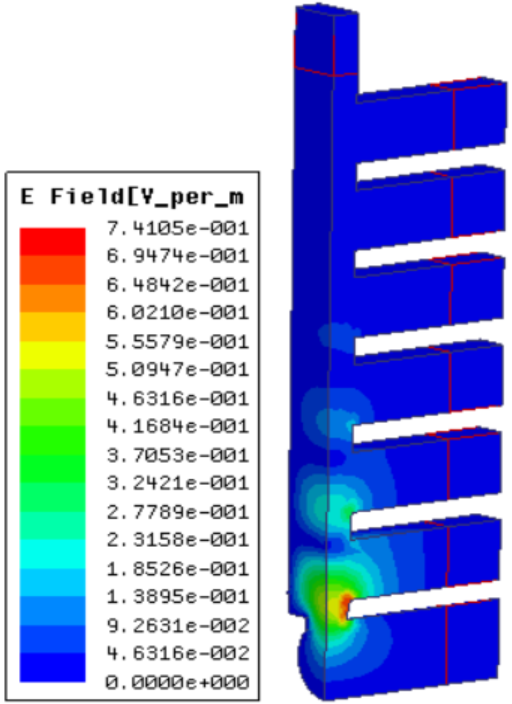


S-parameters of Bragg reflector vs. frequency.

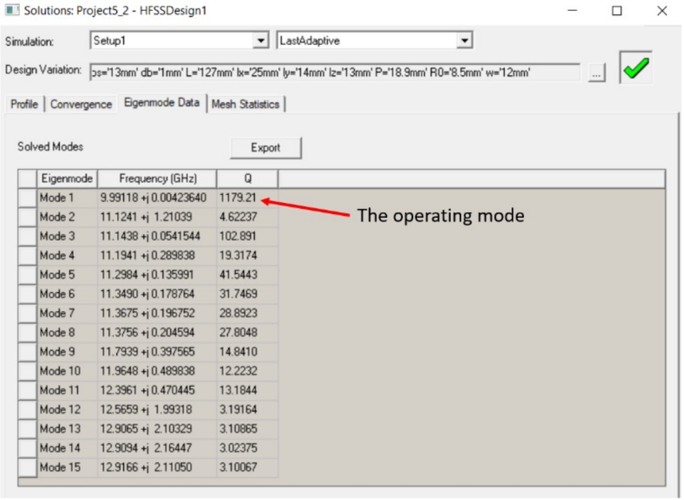


HFSS model

Properties of the 10 GHz QBPM Resonator

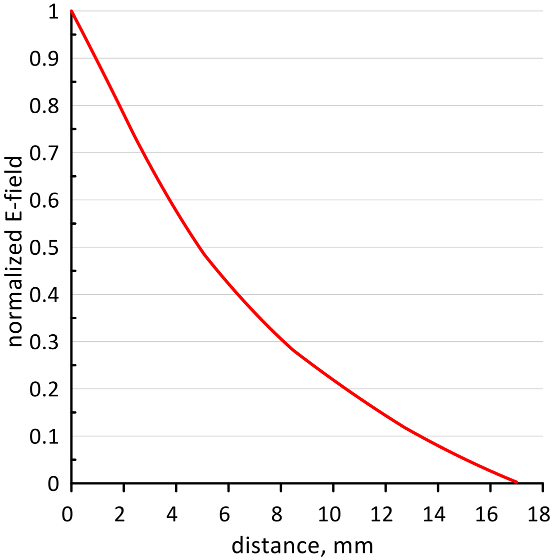


E-field structure of the operating eigenmode.



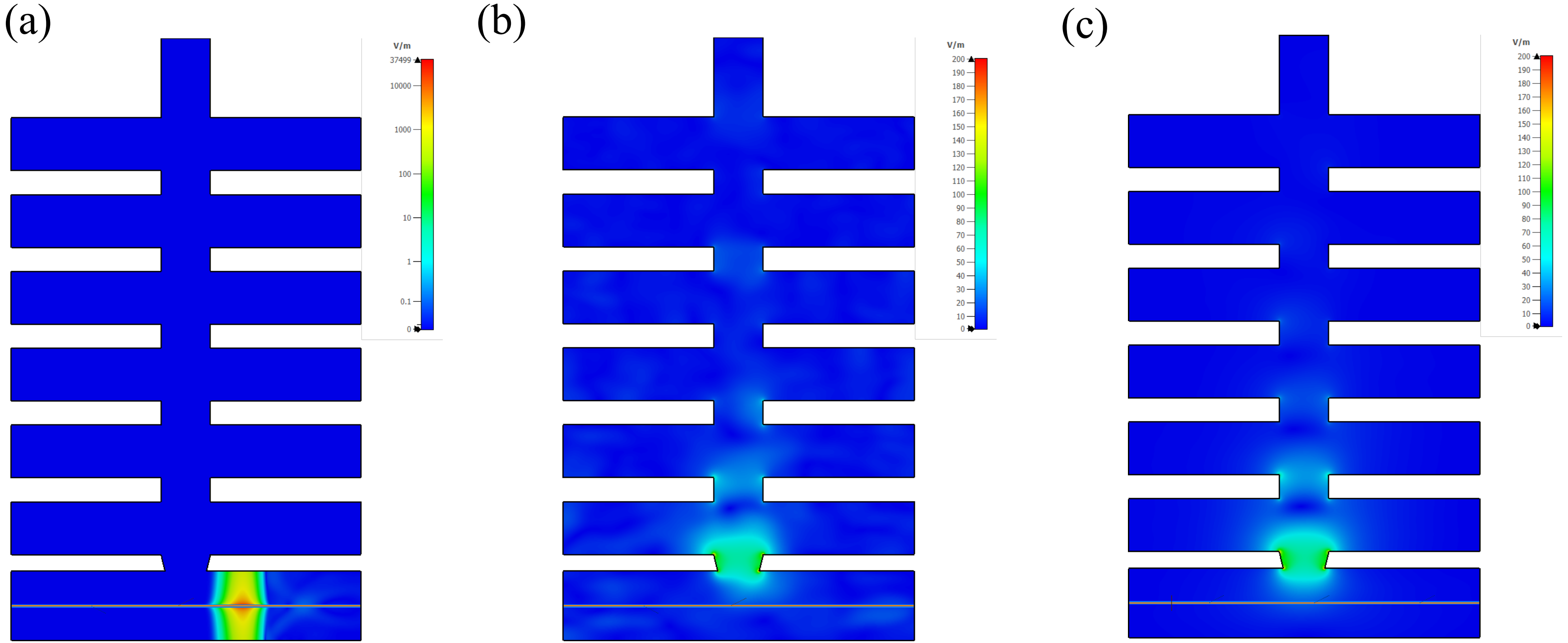
Eigenmode	Frequency (GHz)	Q
Mode 1	9.99118 +j 0.00423640	1179.21
Mode 2	11.1241 +j 1.21039	4.62237
Mode 3	11.1438 +j 0.0541544	102.891
Mode 4	11.1941 +j 0.289838	19.3174
Mode 5	11.2984 +j 0.135991	41.5443
Mode 6	11.3490 +j 0.178764	31.7469
Mode 7	11.3675 +j 0.196752	28.8923
Mode 8	11.3756 +j 0.204594	27.8048
Mode 9	11.7939 +j 0.397565	14.8410
Mode 10	11.9648 +j 0.489838	12.2232
Mode 11	12.3961 +j 0.470445	13.1844
Mode 12	12.5659 +j 1.99318	3.19164
Mode 13	12.9065 +j 2.10329	3.10865
Mode 14	12.9094 +j 2.16447	3.02375
Mode 15	12.9166 +j 2.11050	3.10067

Eigenmodes of the resonator.



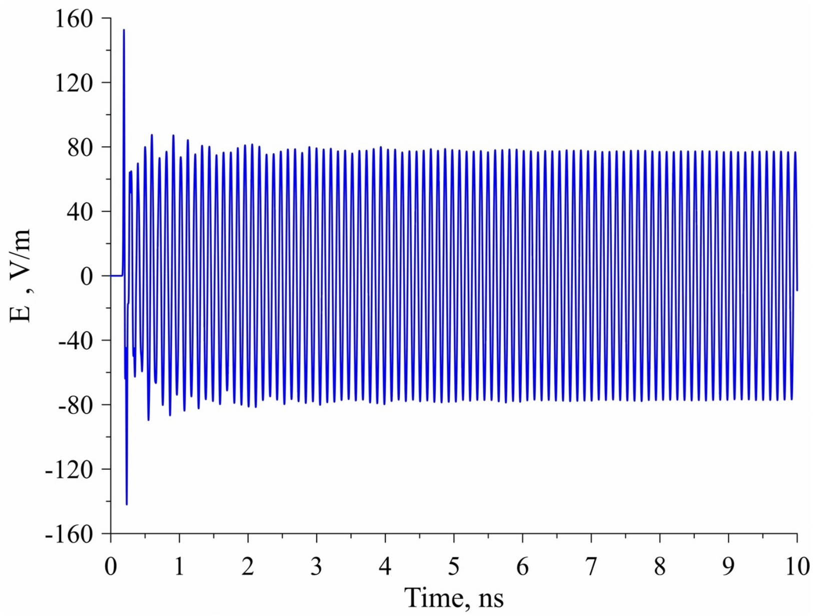
E_x-field near the coupling hole across the beam line.

Simulation of the 10 GHz QBPM with CST Code

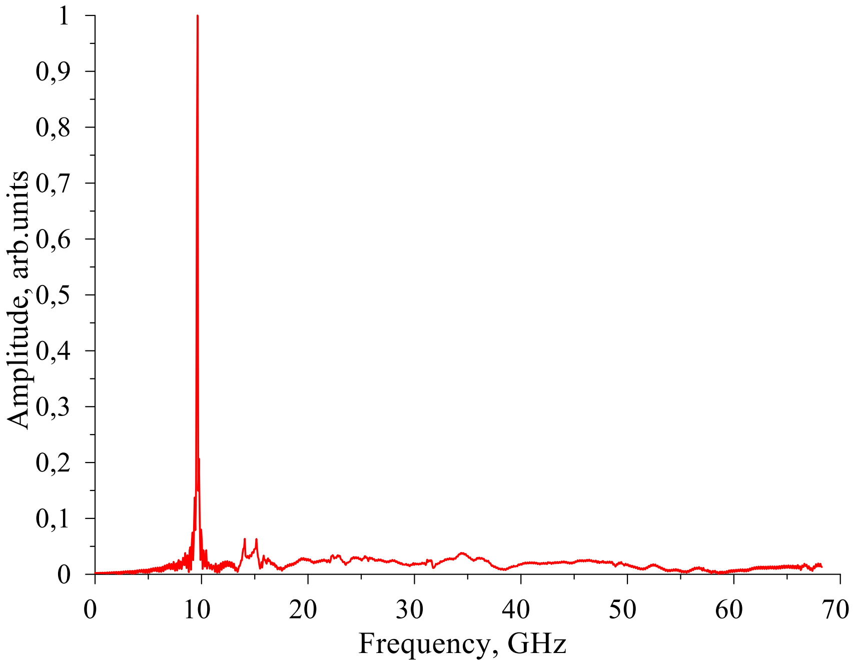


Instantaneous field distribution in the PBG resonator: a – the bunch approaches to the resonator, b – 1 ns after the bunch leaves the coupling area, c – 10 ns after the bunch has passed
The bunch length was set as 10 ps, the charge was 1-pC.

Analysis of Wakefields

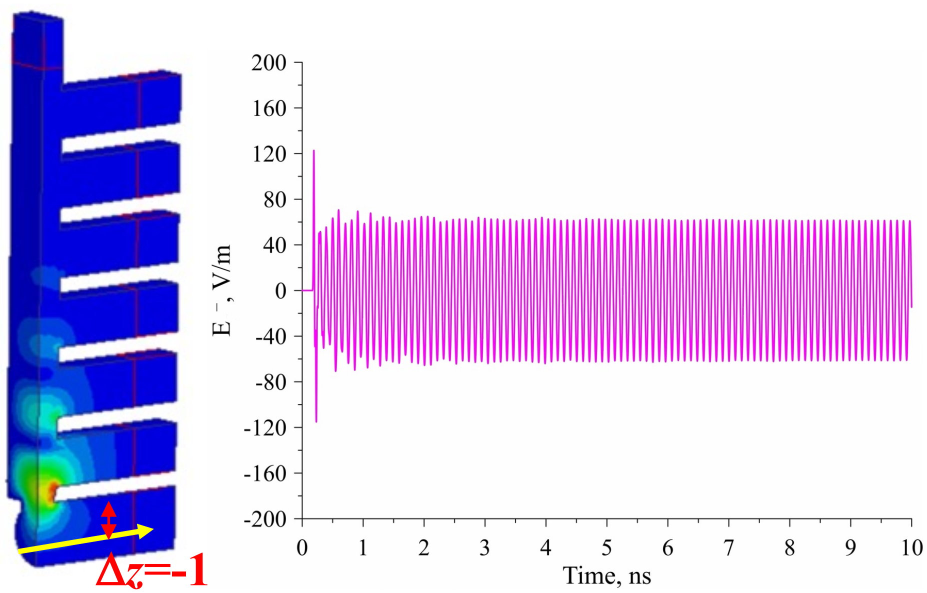


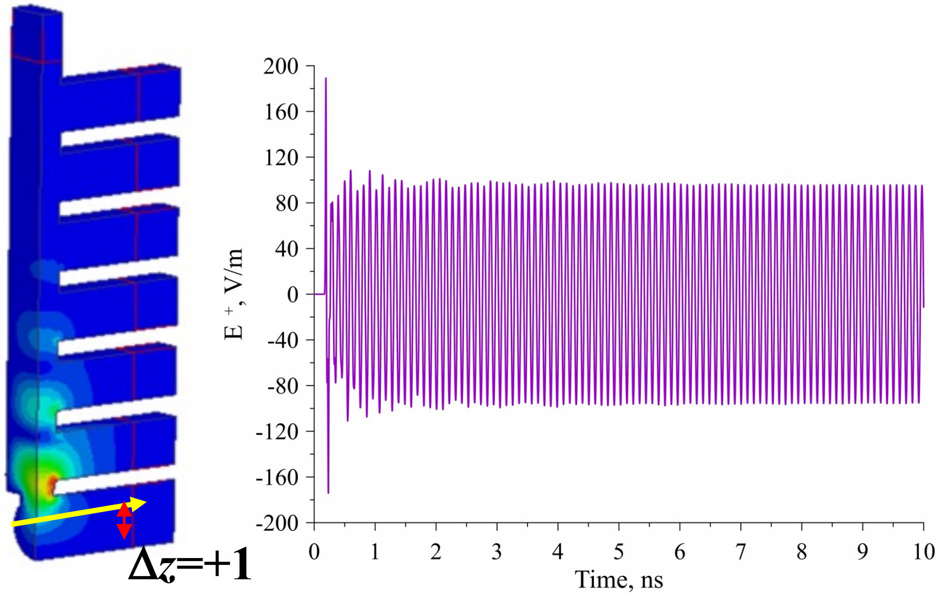
E_x-field component at the resonator when excited by a bunch moving along the *x* axis.



Fourier spectrum for the field excited in the resonator.

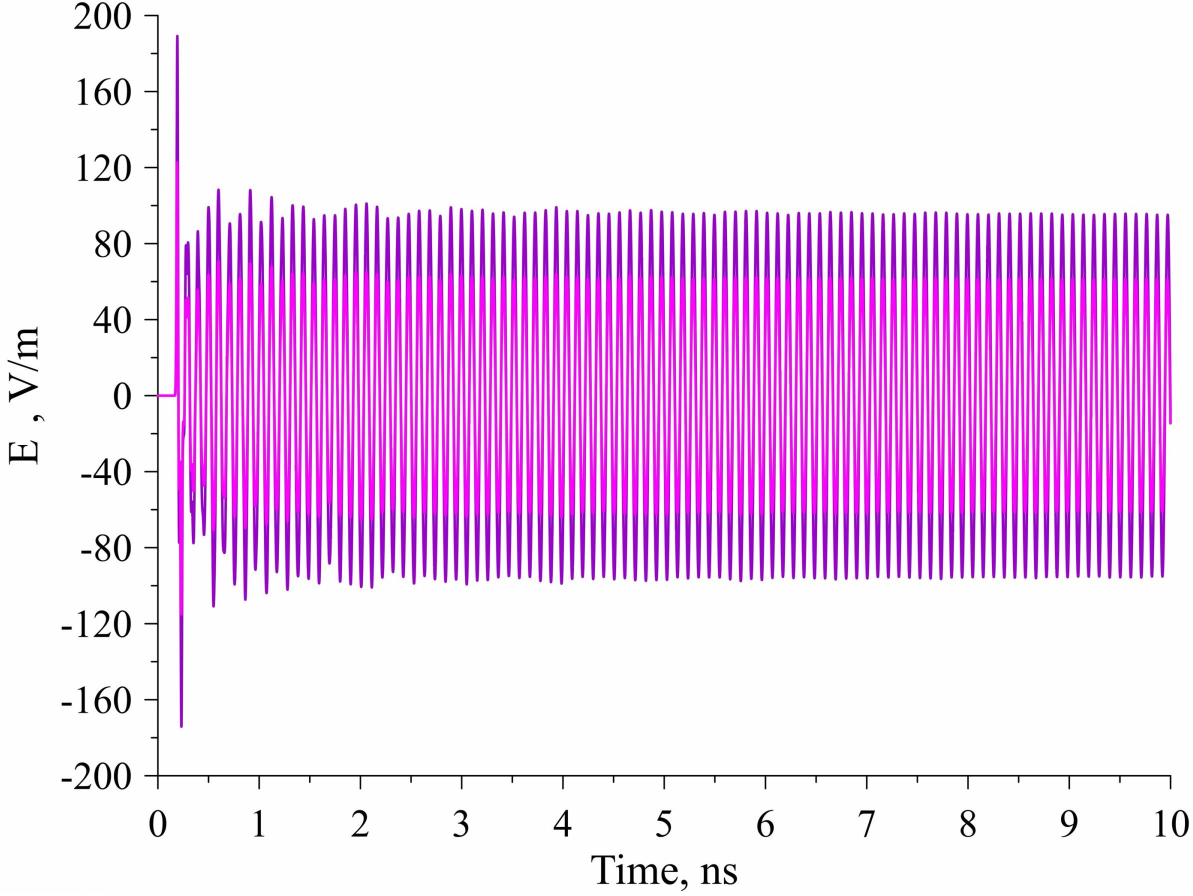
Excitation of the Resonator with Offset Bunches





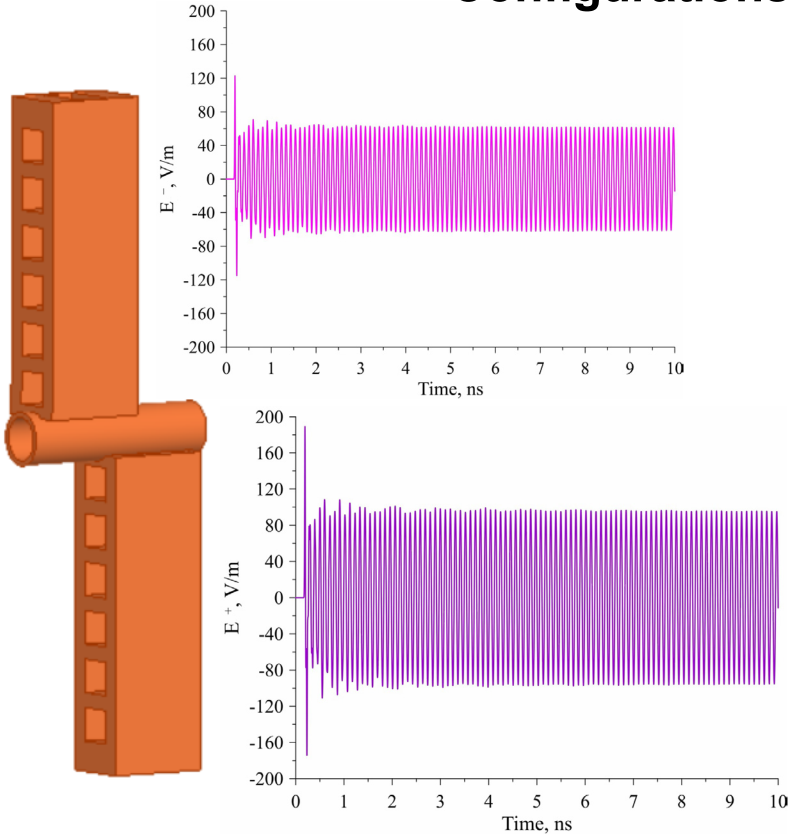
E_x-field component at the PBG resonator when excited by a bunch shifted by **Δz=-1** mm from the x axis.

E_x-field component at the PBG resonator when excited by a bunch shifted by **Δz=+1** mm from the x axis.

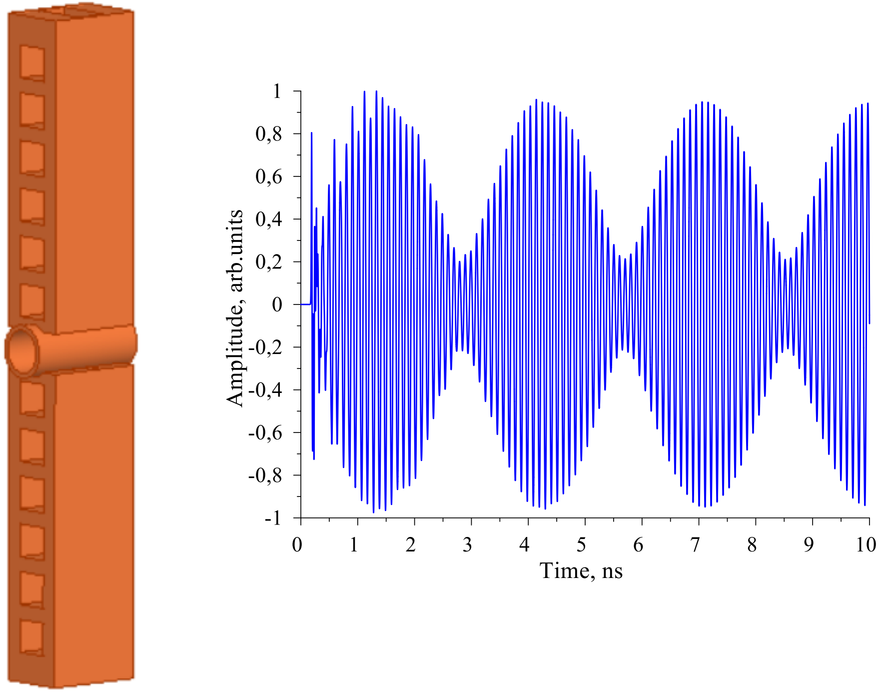


Overlapping of the curves for -1 mm and +1 mm offset bunches.

Configurations of QBPM Measurements



Two independent QBPM resonators



Beat wave excited in the QBPM configuration “face-to-face”.

Conclusion

1. The QBPM can become an efficient tool for diagnostics of short bunches showing excellent mode selection and sensitivity.

2. As short as picosecond bunches can be easily simulated with PC. To simulate femtosecond bunches we plan using of the computer cluster at Fermilab. Estimates show that the 30-node cluster will allow us to simulate bunches as short as 100 fs.