A Step Towards fs-Resolution Arrival-Time Measurements for Ultra-Low Charged Bunches in X-ray Free Electron Lasers

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Motivation

X-Ray Free Electron Laser (XFEL):

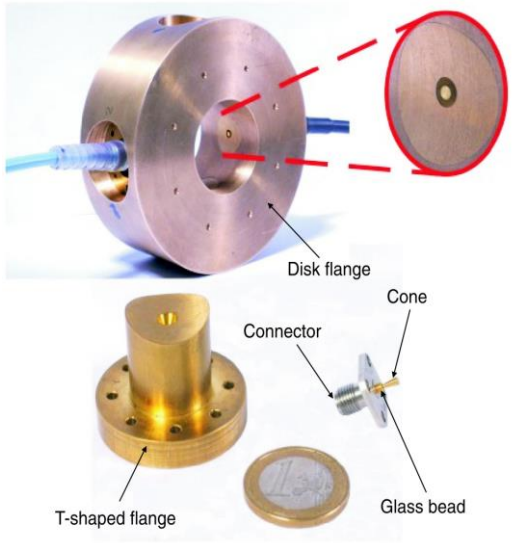
- Experiments on ultra-short time and length scales
- Short, low charge electron bunches used
- Facility wide synchronization necessary
  - All-optical synchronization system
  - Arrival time measurement with fs-resolution

Electro-Optical Bunch Arrival Time Monitor (BAM):

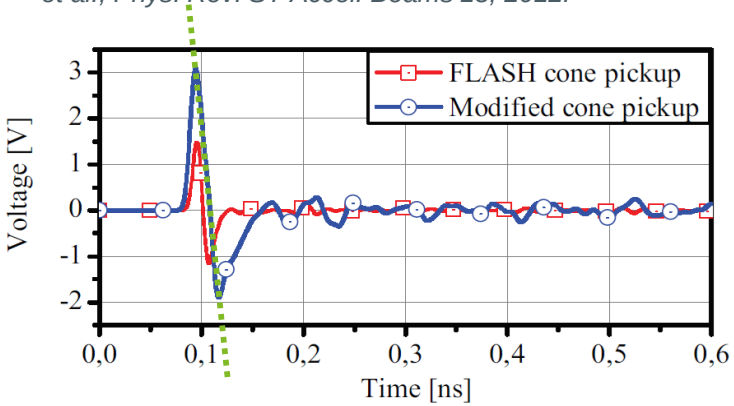
- Cone-shaped button pickups
- Electro-optical modulator
- Pulsed laser reference

→ Sensitivity ∝ slope at zero crossing

$$S/Q \approx 15\ \mathrm{mV\ ps^{-1}\ pC^{-1}}$$



Non hermetic pickup prototype reprinted from Angelovski et al., Phys. Rev. ST Accel. Beams 15, 2012.



Simulated signal in time domain reprinted from Angelovski et al., Phys. Rev. ST Accel. Beams 15, 2012.

BAM Optimization

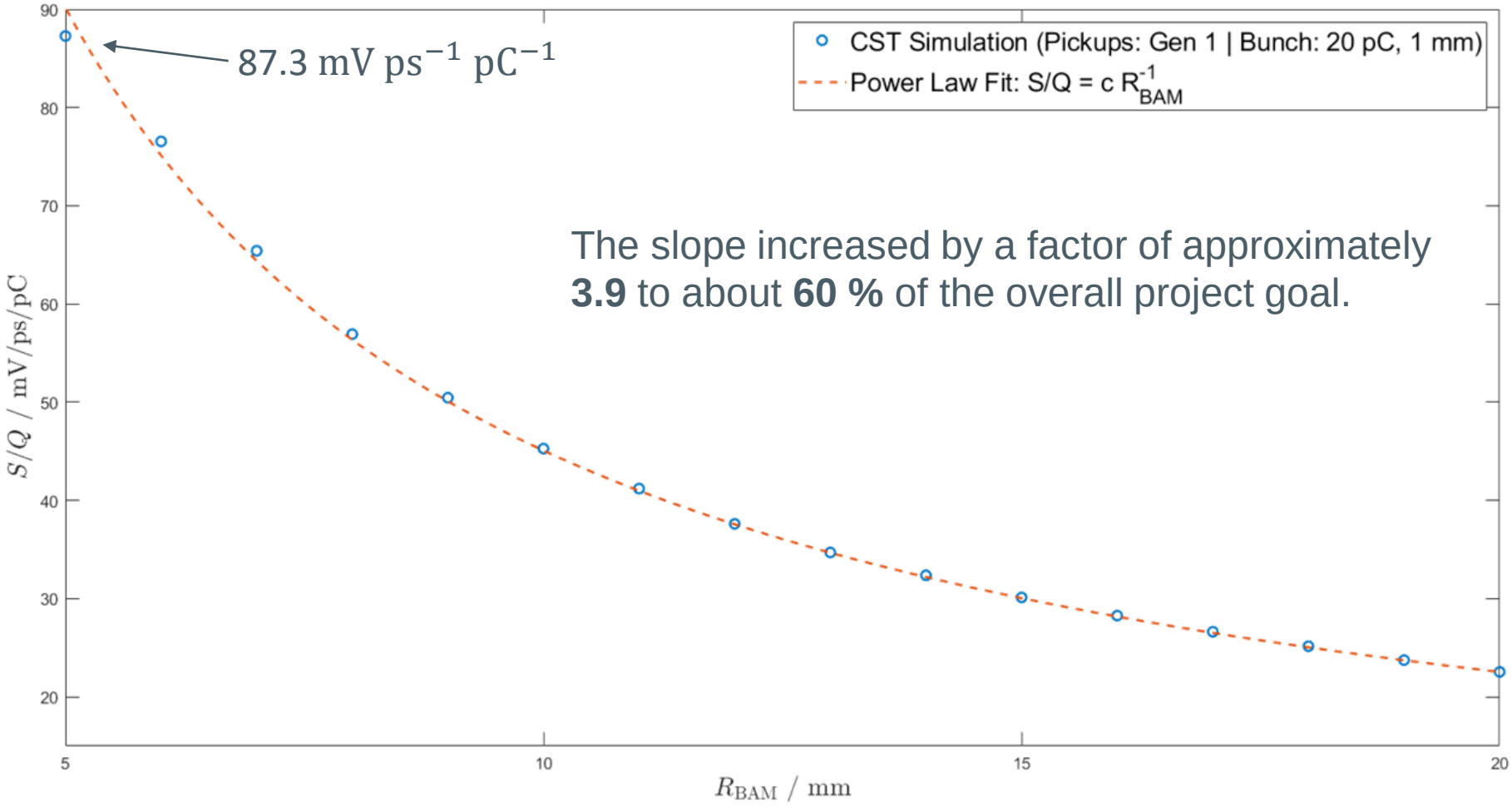
Project Goal

- fs-precision with pC bunches
- Redesign of the RF-system and the EOM
- RF-part: A ten-fold increase of the signal slope $\Rightarrow S/Q \geq 150\ \mathrm{mV\ ps^{-1}\ pC^{-1}}$

Design Options for Improved Pickups

- Reduction of the distance to the beam $S \propto R_{\mathrm{BAM}}^{-1}$
- Increase of the bandwidth
- Further signal combination
- Shorter RF-lines
- …

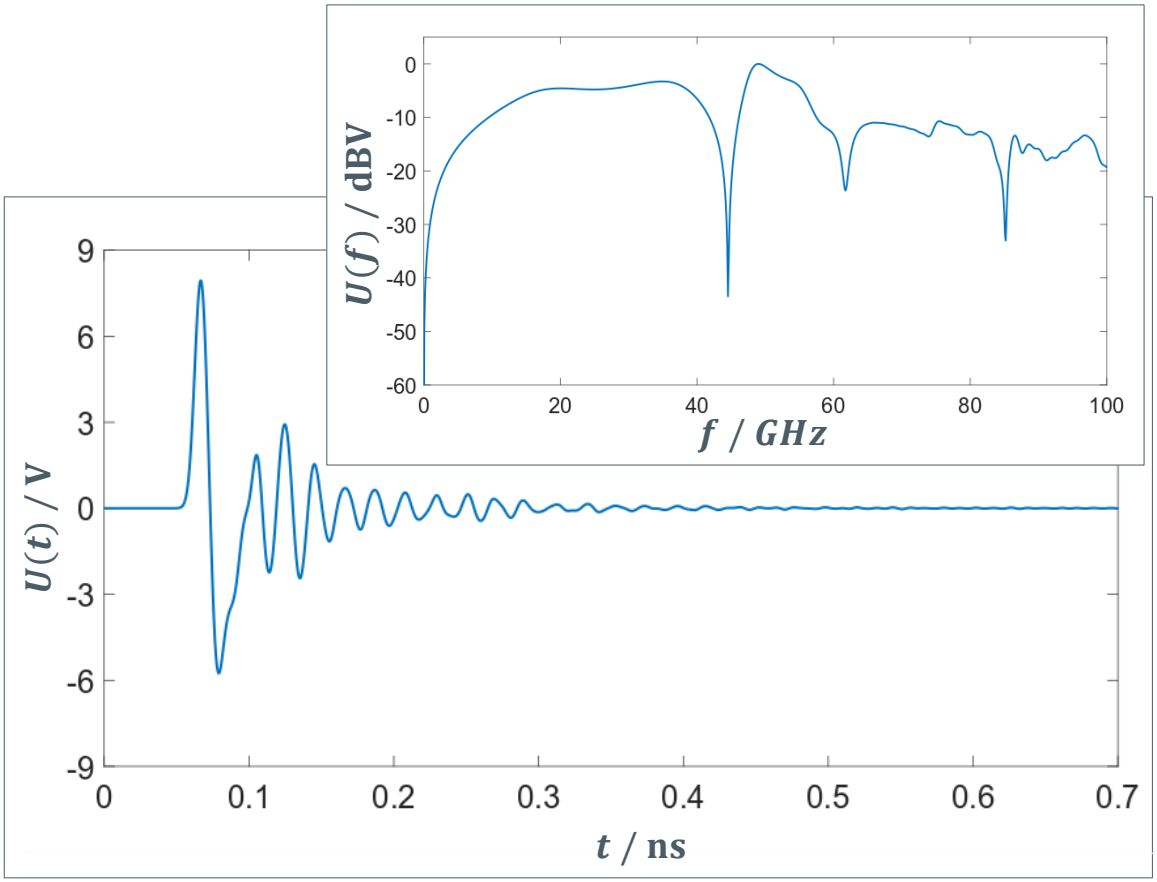
Reduction of R_{BAM} (CST Simulation)

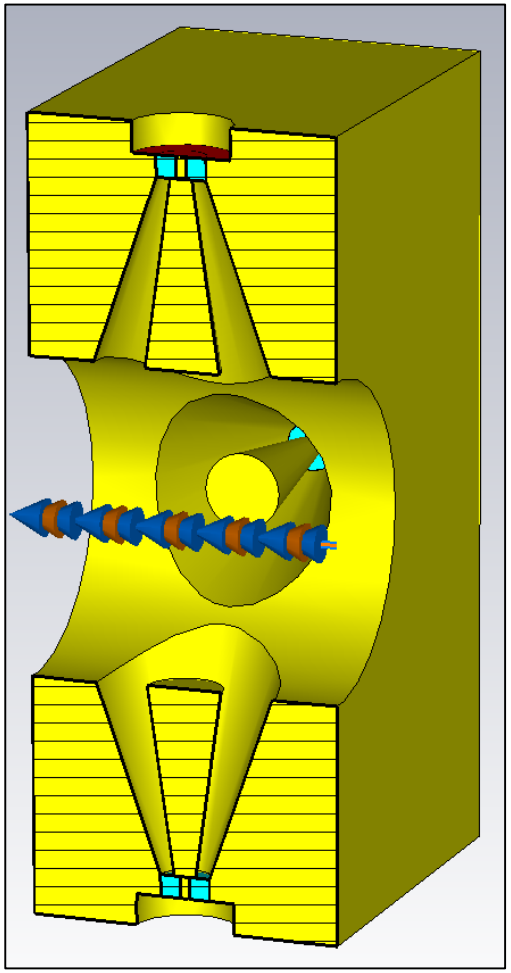


The slope increased by a factor of approximately **3.9** to about **60 %** of the overall project goal.

Reduction of R_{BAM} (CST Simulation)

Scaled Generation 1 Pickup (with $R_{BAM} = 5$ mm)





Simulated signal in time and frequency domain as well as a CST model.

Conclusion and Outlook

- Aperture reduction is a simple solution for lower bunch charges
  - Still undershoots the project goal by a factor of approximately 1.7
- Further improvements are necessary
  - Bandwidth increase is a promising approach
  - New pickup designs under examination

References

A. Angelovski et al., “High bandwidth pickup design for bunch arrival-time monitors for free-electron laser”, Phys. Rev. ST Accel. Beams 15, 112803 (2012). Doi: 10.1103/PhysRevSTAB.15.112803

Acknowledgments

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