ANALYSIS OF NEW PICKUP DESIGNS FOR THE FLASH AND XFEL BUNCH ARRIVAL TIME MONITOR SYSTEM*

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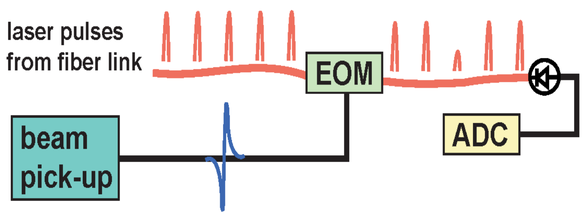
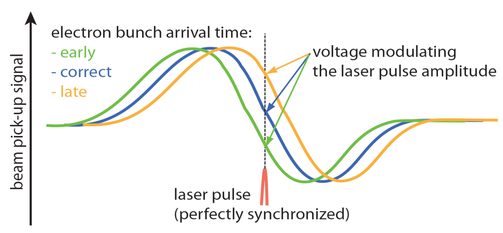
INTRODUCTION

The Free Electron Laser in Hamburg (FLASH) is equipped with Bunch Arrival time Monitors (BAM)[1], which provide for a time resolution of less than 10 fs for bunch charges higher than 0.2 nC. The timing information is obtained by mixing the pickup signal with the pulses of a reference laser in an Electro Optical Modulator (EOM)[2]. This information is coupled back to the first accelerating module, for stabilizing the arrival time jitter of the electron bunches to less than 25 fs. The sensitivity of the measurement system is defined by the slope of the pickup signal at the zero crossing and scales close to linear with the bunch charge. For future experiments lower bunch charges down to 10 pC are of interest. In this case the requirements on the time resolution will no longer be fulfilled. The slope can be increased either by increasing the output signal voltage or its frequency. Due to a technical limitation of the maximum signal voltage a new pickup has to be developed, which has a bandwidth of 40 GHz or higher.





Pictures: H. Schlarb, K. Hacker

SIMULATION SOFTWARE

- CST PARTICLE STUDIO® used as simulation package
- Development of an automated analysis of signal slope and ringing using VBA
- Integrated optimizer tune design parameters on slope and ringing.

The equivalent frequency

$$U(t) = A \cdot \sin(2\pi f_e \cdot t)$$

$$S = \pm A \cdot 2\pi f_e \quad \text{with S as Slope}$$

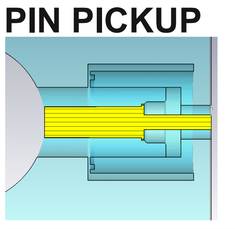
$$\Rightarrow f_e = \frac{|S|}{\pi \cdot U_{\text{peak to peak}}} \quad \text{with} \quad U_{\text{peak to peak}} = 2 \cdot A$$

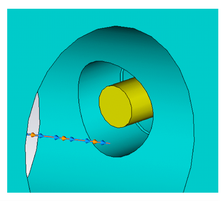
- Compute with CST
  - peak-to-peak voltage
  - equivalent frequency
- All simulations using Gaussian bunches
  - longitutinal standard deviation of σ = 1 mm
  - 20 pC bunch charge.

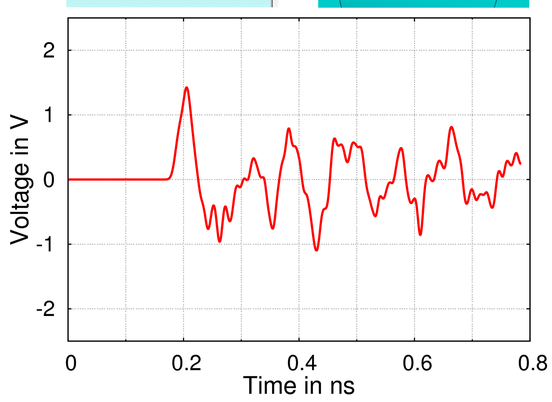
PICKUPS

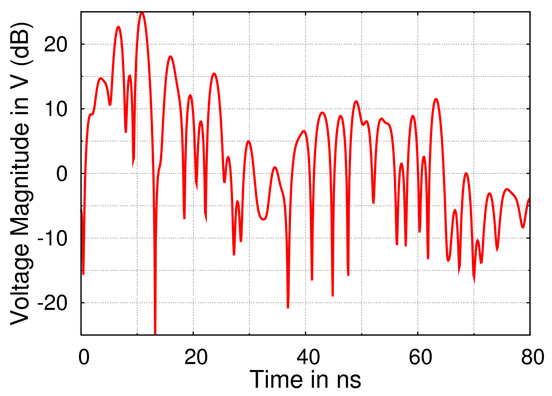
CURRENT PICKUP

PIN PICKUP





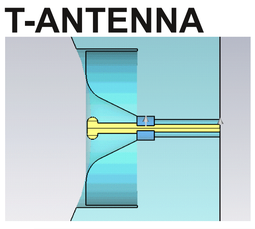


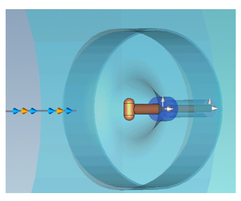


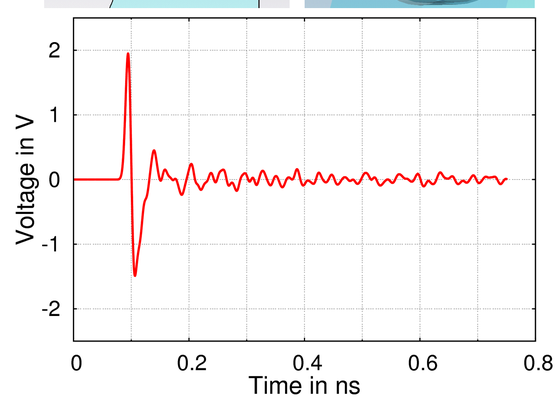
Slope:	69.7 mV/ps
Ringing after 0.3 ns:	> 67 %
$U_{peak\ to\ peak}$:	2.52 V
f_e:	8.78 GHz

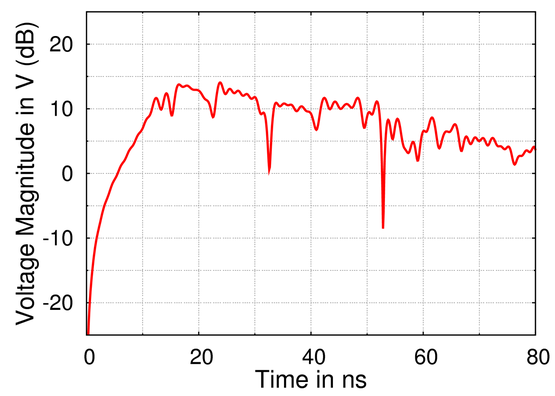
NEW PICKUP DESIGNS

T-ANTENNA



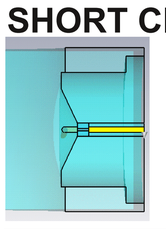


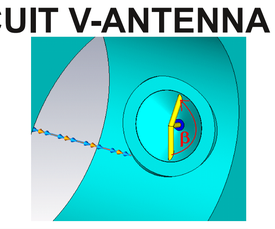


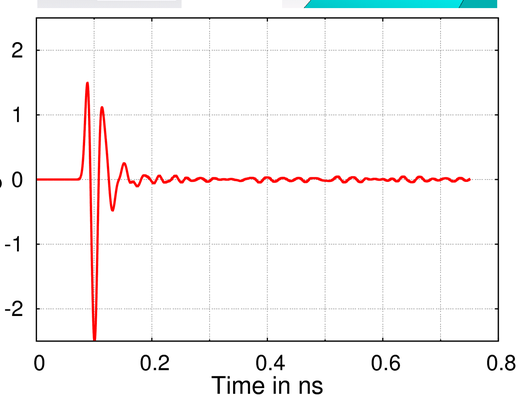


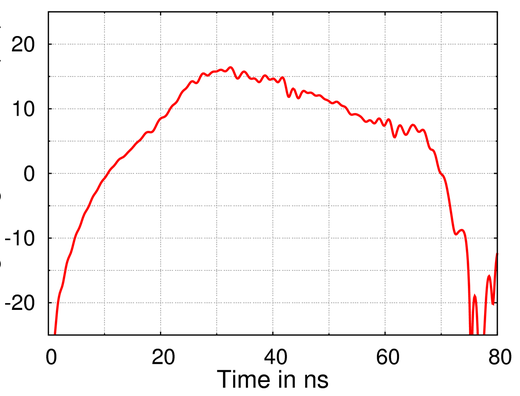
Slope:	479 mV/ps
Ringing after 0.3 ns:	6.39 %
$U_{peak\ to\ peak}$:	3.44 V
f_e:	44.4 GHz

SHORT CIRCUIT V-ANTENNA



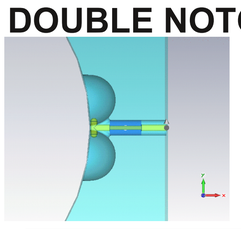


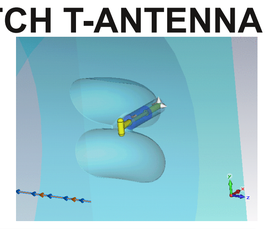


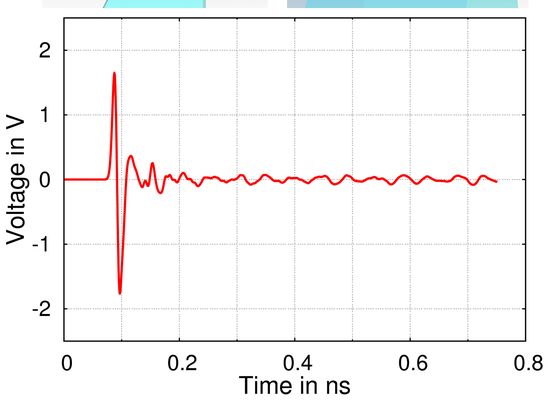


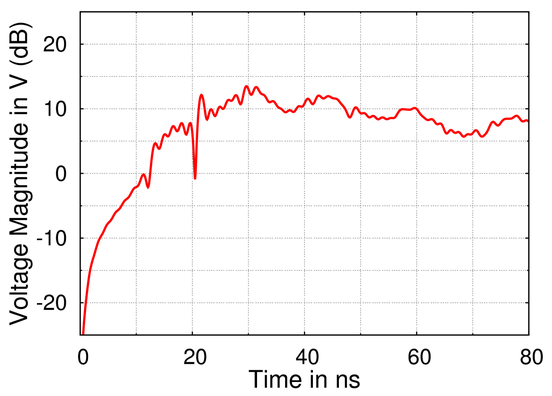
Slope:	499.7 mV/ps
Ringing after 0.3 ns:	2.32 %
$U_{peak\ to\ peak}$:	4.01 V
f_e:	39.7 GHz

DOUBLE NOTCH T-ANTENNA









Slope:	604.4 mV/ps
Ringing after 0.3 ns:	4.8 %
$U_{peak\ to\ peak}$:	3.41 V
f_e:	56.45 GHz

CONCLUSIONS

Specifications of the new pickup:
- Slope greater than 300 mV/ps
- Ringing below 0.1 % after 220 ns.

New designs
- Sporadic long term simulations were made
  - Ringing below 0.1 % after 10 ns
- Enable time measurements down to 10 fs with bunch charges as low as 20 pC.
- Reduced ringing
  - less then 7 % after 0.3 ns

OUTLOOK

- Sensitivity analysis
  - Necessary for determining production tolerances.
- One selected design will be built [4]
  - non-vacuum compatible prototype to be measured and compared with simulation results
- A vacuum compatible prototype will be built and installed in the FLASH facility.

REFERENCES

[1] M. K. Bock et al., "Recent Developments of the Beam Arrival Time Monitor with Femtosecond Resolution at FLASH", Proceedings of the IPAC 2010, Kyoto, Japan

[2] F. Loehl, "Optical synchronization of a free-electron laser with femtosecond precision", DESY-TESLA-FEL-2009-08

[3] K. Wille translated by J. McFall, "The Physics of Particle Accelerators", Oxford University Press, New York, 2000

[4] A. Angelovski et al. "Realization of a High Bandwidth Bunch Arrival time Monitor with Cone-shaped Pickup Electrodes for FLASH and XFEL", to appear in Proceedings of the DIPAC 2011, Hamburg, Germany

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* The work of A. Kuhl, A. Angelovski is supported by German Federal Ministry of Education and Research (BMBF) within Joint Project - FSP 301. Also, A. Kuhl and S. Schnepp are supported by the 'Initiative for Excellence' of the German Federal and State Governments and the Graduate School of Computational Engineering at Technische Universität Darmstadt.