Concept of a novel high-bandwidth arrival time monitor for very low charges as a part of the all-optical synchronization systems at XFEL and FLASH

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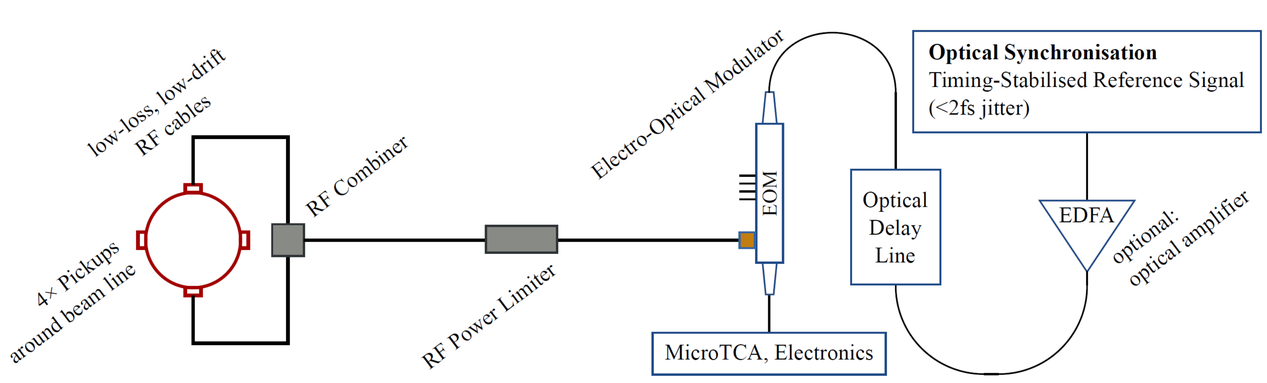
MOTIVATION

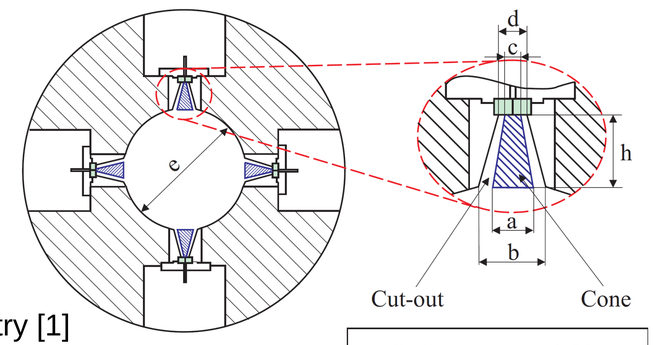
Numerous advanced applications of X-ray free-electron lasers require pulse durations and time resolutions in the order of only a few femtoseconds or better. The generation of these pulses to be used in time-resolved experiments require synchronization techniques that can simultaneously lock all necessary components to a precision in the range of 1fs only. To improve the experimental conditions at existing facilities and enable future development of seeded FELs, a new all-optical synchronization system at FLASH and XFEL was implemented, which is based on pulsed optical signals rather than electronic RF signals. In collaboration with DESY, Hamburg, the all-optical synchronization system is used to ensure a timing stability on the 10fs scale at XFEL.
For a future ultra-low charge operation mode down to 1pC at XFEL an overall synchronization of (5+1)fs r.m.s. or better is necessary.
This contribution presents a new concept for an ultra-wideband pickup structure for beampipe-diameters down to 10mm for frequencies up to 100GHz or higher and at the same time providing sufficient output signal for the attached EOMs.

BAM PRINCIPLE



Basic layout of the cabling scheme of a single channel (picture taken from [3])

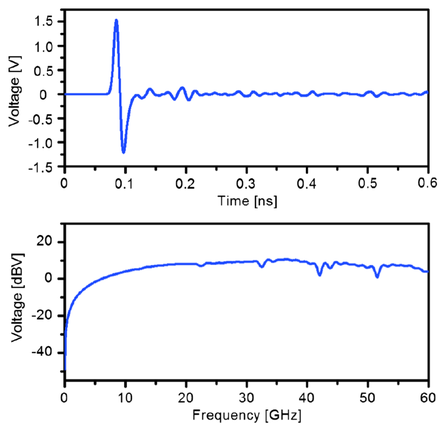
CURRENT BAM PICKUP



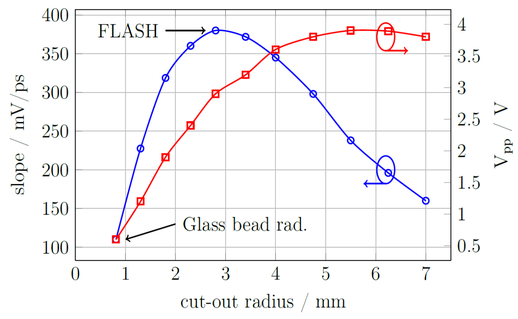
Pickup geometry [1]
- Resonance free up to 40GHz
- External cabling using low loss SiO_2 cables

a = 2.42 mm	c = 0.70 mm
b = 5.60 mm	d = 1.62 mm
e = 40.50 mm	h = 6 mm

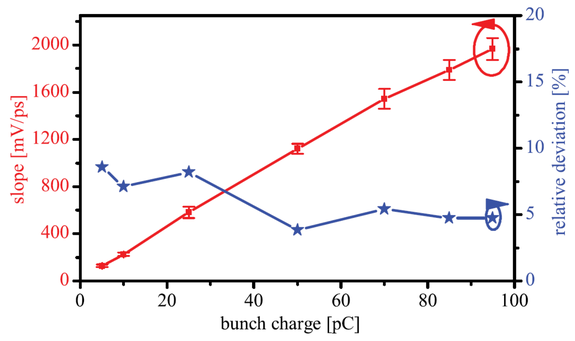
SENSITIVITY ANALYSIS



Simulation results of one pickup [1]

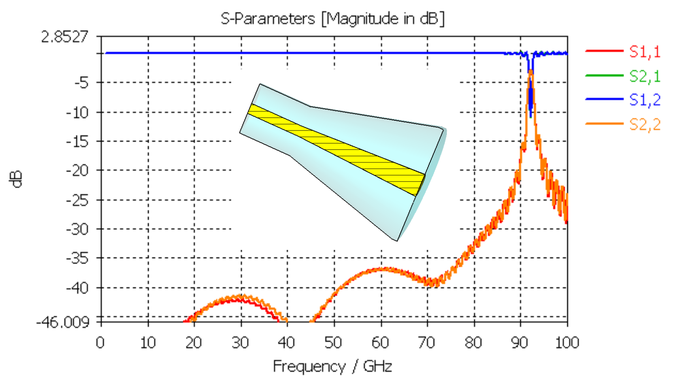


Simulated slope and voltage of a single pickup as a function of the cut-out radius for a bunch charge of 20pC [4]



Measured pickup signal slope dependence of the bunch charge at ELBE. Blue curve shows the relative slope deviation for 128 shots [2]

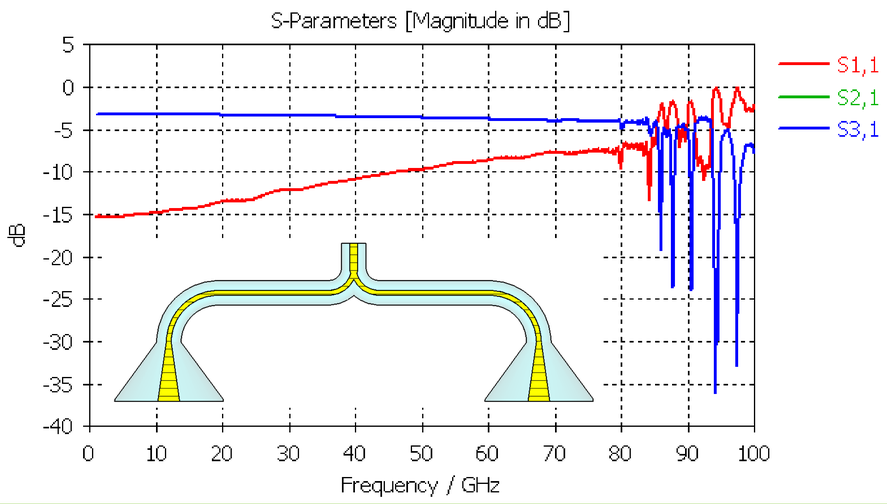
PROPOSED PICKUP STRUCTURE

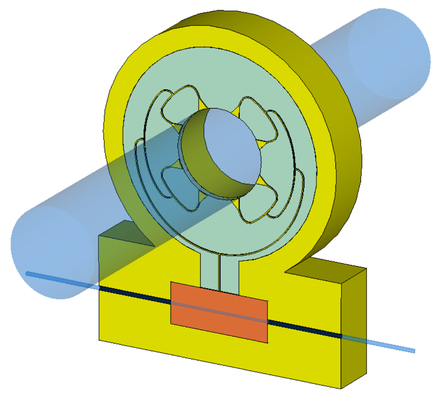


Simulation results of the tapered pickup structure up to 100GHz

COMBINATION OF PICKUPS USING INTEGRATED COAXIAL LINES

- Broadband combination of two pickups using impedance matching technique
- Low insertion loss and resonance free up to 80GHz
- Combination of multiple pickups to
  - Ensure sufficient signal strength to drive the attached EOM
  - Reduction of orbit dependency





- Possible solution for 8 pickup BAM geometry
- 1mm coax connector (50Ω) or direct connection to attach EOMs

CONCLUSION

- Systematic investigation of possible integration techniques for pickups and transmission lines at high frequencies up to 100GHz
  - Dispersion of transmission lines for pulsed signals – Minimization of the structure is mandatory
  - Signal degradation due to losses needs to be minimized for ultra-low charge operation down to 1pC
- Discontinuities within the pickup structure need to be prevented in order to minimize the excitation of wakefields in the beam pipe

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