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TEO-BAM –WP1: Innovative mmW pickup structures: Development of an ultra-low-charge BAM pickup geometry for fC operation modes

Operating high-gain FELs with ultra-low bunch charges around 1~pC or even less enables the generation of ultra-short, coherent pulses with significantly higher brightness, opening the path to explore processes at attosecond timescales [1]. Similar requirements exist for next-generation ultrafast electron diffraction (UED), which demands sub-pC bunches and arrival-time monitoring with single-digit femtosecond precision.

Bunch arrival-time monitors (BAMs) based on electro-optical (EO) methods are already established at facilities such as FLASH, EuXFEL, ELBE, SwissFEL, and others [2,3]. They provide quasi non-invasive measurements relative to a sub-fs synchronized laser pulse, reaching 3.5~fs resolution for 250~pC bunches at EuXFEL \cite{ref14}. However, adapting these systems for low-charge operation is necessary, since sensitivity strongly depends on bunch charge \cite{ref15}.

A previous project (05K19RO1) developed new broadband pickup structures exceeding 100~GHz bandwidth, showing promising results [4]. These concepts were further validated as a demonstrator at ELBE [5]\cite{ref18,ref19}. The proposed work aims to realize Mach–Zehnder-type EOMs and pickup structures with integrated networks to achieve sub-10~fs resolution for sub 1~pC bunches [6]. Prototypes will be tested at facilities such as REGAE (DESY), FLUTE (KIT), ELBE (HZDR) to enable applications at EuXFEL, FLASH, and future FEL facilities.

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Primary author: PENIRSCHKE, Andreas (Technische Hochschule Mittelhessen)

Co-author: SCHEIBLE, Bernhard (Technische Hochschule Mittelhessen)

Presenter: PENIRSCHKE, Andreas (Technische Hochschule Mittelhessen)

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