HOM CHARACTERIZATION FOR BEAM DIAGNOSTICS AT THE E-XFEL INJECTOR.

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Abstract
Higher Order Modes (HOM) excited by bunched electron beams in accelerating cavities carry information about the beam position and phase. The principle is used in the HOM facility at DESY to provide RF power coupled to the E-XFEL injector cavities. These HOM signals, which depend on the beam offset, are used. Similar modes are now under design for the European XFEL. In addition to beam position, the beam phase with respect to the accelerating RF will be monitored using monopole modes from the first higher order mode cavity band. The HOM signals are available from two couplers installed in each cavity. Their monitoring will allow us to track the beam position and phase, but also allows us to improve the stability of the facility. As part of the project designing the HOM facility, the HOM spectra of the modes of the 1.3 and 3.9 GHz cryo-modules installed in the European XFEL injector have been measured. This paper will present their dependence on the beam position. The variation in the mode distribution from cavity to cavity will be discussed. Based on the results, initial phase measurements have been made. To be used for beam phase measurement.

Beam spectra for 1.3 GHz cavities in E-XFEL injector

Spectra were measured with Tektronix RSA216H for each cavity around the frequencies of interest for HOM-based diagnostics.

Dipole modes at ca. 1.7 GHz
- Two polarizations of the modes can be identified.
- Vertical line is mode frequency from transmission measurements.
- Monopole modes around 2.4 GHz
- Vertical lines: expected modes from transmission measurements.
- Additional peaks were found to be modes from neighboring cavities. No problem for HOM-based phase diagnostics.

HOM spectra of a TESLA cavity

Monopole modes
- Monopole modes are used to detect the beam position. Their amplitude varies linearly with the transverse beam position and charge.
- Dipole modes
- Dipole modes can be used for beam position monitoring. This principle is used at the FLASH facility, at DESY, for accelerating cavities carry information about the beam position and phase. The principle is used in the HOM facility at DESY to provide RF power coupled to the E-XFEL injector cavities. These HOM signals, which depend on the beam offset, are used. Similar modes are now under design for the European XFEL. In addition to beam position, the beam phase with respect to the accelerating RF will be monitored using monopole modes from the first higher order mode cavity band. The HOM signals are available from two couplers installed in each cavity. Their monitoring will allow us to track the beam position and phase, but also allows us to improve the stability of the facility. As part of the project designing the HOM facility, the HOM spectra of the modes of the 1.3 and 3.9 GHz cryo-modules installed in the European XFEL injector have been measured. This paper will present their dependence on the beam position. The variation in the mode distribution from cavity to cavity will be discussed. Based on the results, initial phase measurements have been made. To be used for beam phase measurement.

HOM-based beam phase monitoring

Principle
- Measure RF signal and beam-scan signal

Experimental setup
- Delays of 0.12deg and 0.06deg
- Resolutions obtained with the experimental setup of 0.06deg (obtained by comparing results from both couplers).

Summary
In preparation for the HOM-based diagnostics now under design for the E-XFEL, we analysed the HOM spectra in the first five 1.3 GHz modules and the 3.9 GHz module. The selected modes are within the bandwidth of the electronics. For the monopole modes one could also observe peaks from the neighbouring cavities, which do not constitute a problem for the phase monitoring. The dependence of the dipole spectra on the beam position was analysed. There is a variation from cavity to cavity in the polarization rotation, which makes a complex signal processing necessary. Further measurements are planned after the start of beam operation of the entire E-XFEL Linac, and when the prototype electronics is available for beam tests.

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HOM spectra

First 5 TESLA/3.9 GHz modules
- Transmission spectra (GT) were measured for each 1.3 GHz cavity during RF tests.
- Dipole modes: data taken from cavity database.
- Monopole modes: data taken from cavity database.
- Models with high IQ (band ≥ 10^5), as implied by beam phase.
- Models: Note that modes have modes shifted to higher frequency, but still within electronics bandwidth.

HOM spectra

1.3 GHz
- Monopole modes propagating in the whole 8-cavity module.
- Dipole modes: data taken from cavity database.
- Band around 3.4 GHz chosen for monopole related beam monitoring.
- Band around 5.4 GHz chosen for localized monitoring.

The European XFEL

Linac

Max. energy [GeV] 17.5
Bunch length [ns] 0.02 - 1
Max. bunch frequency [MHz] 4.5
Max. bunch number: pulse 3000
Pulse repetition frequency [Hz] 10
Max. input power [MW] 400