Electron Cyclotron Emission Imaging on KSTAR

Neville C. Luhmann, Jr., Calvin W. Domier, Kerry Gong, Tianran Liang, University of California at Davis, Davis, CA, USA
Woongchan Lee, Hyeon K. Park, Gunso Yun, Pohang University of Science and Technology (POSTECH), Pohang, Gyeongbuk, Korea
Benjamin Tobias, Princeton Plasma Physics Laboratory (PPPL), Princeton, NJ, USA

Abstract

Electron Cyclotron Emission Imaging (ECEI) technology is a widely used technique to measure plasma electron temperature profiles and fluctuations in magnetized plasmas. ECEI Imaging (ECEI) is a technique which combines 1-D vertically-aligned imaging arrays with wide bandwidth electronic arrays to form temporally resolved images of the 2nd harmonic X-mode ECEI radiation emitted from tokamak plasmas. In the case of KSTAR, to unique optical port design allows unrestricted window access for the implementation of a state of the art imaging system. UC Davis, in collaboration with PPPL, has developed a high performance optical system for the KSTAR device employing simultaneous low and high field side imaging, continuous vertical focusing and focusing control, invariant toroidal beam focusing, and significantly increased plasma coverage in both vertical and radial directions has been designed. The KSTAR ECEI system comprises two separate ECEI arrays, each with its own low cost (LO) source and focusing optics, but with shared vertical optics [1]. A cassette penetrated the vacuum wall and is inserted deep into a tokamak vessel port. A large window mounted on the plasma end of the cassette. This unique design brings the plasma facing optical elements closer to the plasma while also allowing the entire optical system to be placed out-of-vacuum for easier installation, operation, and maintenance. The zoom optical elements are placed within a port cassette on the superconducting KSTAR device, and determine the vertical extent of the images formed by the two imaging arrays. Each imaging array has its separate focusing optical elements outside the cassette for controlling the radial focusing of the image.

UC Davis is presently fabricating a third ECEI array, to be placed on a remotely separated port on KSTAR, which will provide full vertical coverage for KSTAR by adding toroidal T0 data to the 2D radial and poloidal ECEI data collected by the existing system and thereby allow a better understanding of the 3D nature of the magnetic reconnection phenomena, among the many physics areas under investigation on KSTAR. Details of both ECEI systems will be presented, including both optical and electronic designs and performance.

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ECE Imaging: Principles of Operation

- **Double down-conversion scheme**: Plasma radiation (ECEI) is imaged onto array of dual dipole antennas, and is inserted deep into a tokamak vessel port. A large window mounted on the plasma end of the cassette. This unique design brings the plasma facing optical elements close to the plasma while also allowing the entire optical system to be placed out-of-vacuum for easier installation, operation, and maintenance. The zoom optical elements are placed within a port cassette on the superconducting KSTAR device, and determine the vertical extent of the images formed by the two imaging arrays. Each imaging array has its separate focusing optical elements outside the cassette for controlling the radial focusing of the image.

- **Individual view windows corresponding to the detector arrays, donated by HBS (high-field side) and LFS (low-field side), can be placed anywhere in the plasma, including the border case (equatorial plane)
- **Each 2nd harmonic X-mode detector array provides 24 (vertical) or 8 (horizontal) ECEI profiles with a spatial resolution -1.2 cm and a time resolution -1 ms**

ECEI Imaging: Modules 2.1-9.2 GHz

- **ECEI System in 2012**:
  - Optical zoom and focal plane translation, coupled with IF electronics providing radial zoom, yield a wide range of available poloidal images. High resolution imaging (left) with spot sizes as small as 1 cm at WHIM. In wide zoom (right), nearly a full meter of vertical plasma coverage is possible.

- **Number of vertical channels**: 24
- **Total number of lenses**: 4 for each array, 2 shared
- **Advance elements**:
  - Frequency range: 800 MHz
  - Field of view: 31.7°
- **Maximum lens thickness**: 133 mm
- **Variable radial plasma coverage**: 0.5 – 300 mm (LFS), 0.5 – 300 mm (HFS)
- **Variable vertical plasma coverage**: 300 mm – 800 mm (LFS), 300 mm – 800 mm (HFS)
- **Variable vertical spot radius**: 11 mm – 34 mm
- **Horizontal spot radius**: 23 mm
- **Tilt angle**: 0°
- **Total length**: 479 mm

- **ECEI System #1, #2**
- **ECEI Systems #1, #2**:
  - Ready for use

Addition of 3rd ECEI System in 2012

- **A third ECEI system, together with a microwave imaging reflectometer (MIR) system, will be installed on KSTAR in 2012.**
- **The array and associated electronics are presently under fabrication at UC Davis, and will be delivered to KSTAR in May, 2012.**
- **Like ECEI systems and 2, the third ECEI system is comprised of a 2448 imaging array with variable zoom/lens options and IF electronics operating at 2.1-9.2 GHz.**