Development of an electron cyclotron emission imaging system

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Development has continued for an Electron Cyclotron Emission (ECE) imaging system that will make measurements on the Cyclotron Institute's Electron Cyclotron Resonance Ion Sources (ECRIS). The ECE imaging system could give many new insights into ECRIS plasma dynamics by directly measuring the absolute energy distribution and relative number density of electrons in the plasma.

Much of the development over the past year was focused on using simulations to improve a central element of the camera, the Electronically Variable Reflective Surfaces (EVRS). These metamaterial arrays will be used as shutters and frequency-selective beamsplitters, able to bandpass ECE signals and overlay local oscillator reference signals. Compared to previous iterations, the new EVRS (Fig. 1) cell design simulations show no unwanted harmonic resonances and much lower out-of-band reflectivity.

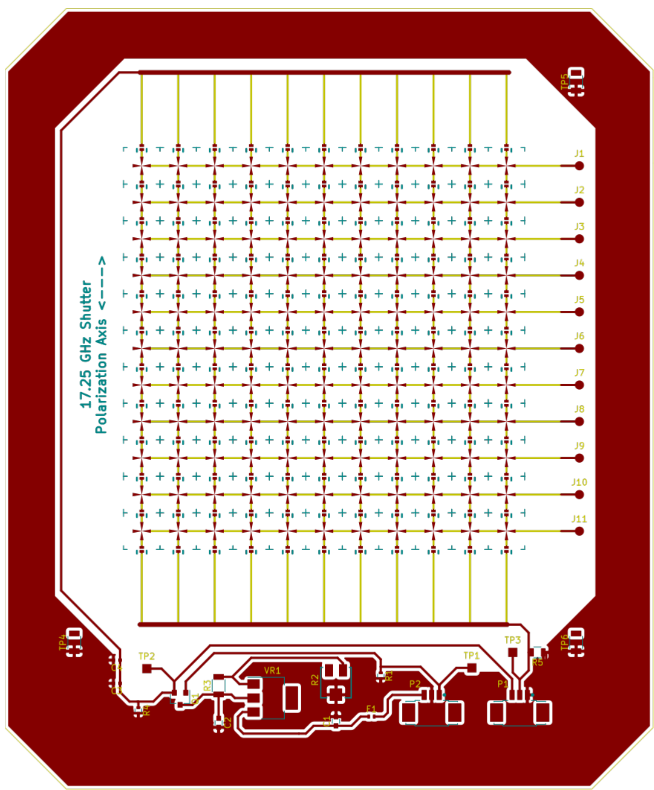

Fig. 1. EVRS board.

Once this satisfactory EVRS array cell was found, prototype printed circuit boards (PCB) were designed and fabrication was initiated. The EVRS PCB integrates the array with support electronics for cycling the power state and generating diagnostic signals. These EVRS boards will be driven, synchronized, and monitored in clusters by dedicated controller boards that are also in development.

Other critical components of the imaging system were also redesigned. The optical layout of the full ECE imaging system was changed and simplified in order to fit laboratory space constraints. The new layout (Fig. 2) routes the signal vertically out of the ECRIS and over the x-ray shield to the top of a server rack (containing the EVRS filters, detector array, and data capture computers). The vertical orientation of the vacuum optics in this new layout required a reconsideration of their mounting hardware and installation procedure, and the new mounting system is a substantial improvement. Besides mechanical simplicity, its lack of metal fixtures prevents a resonant heating mode in the primary lens assembly.

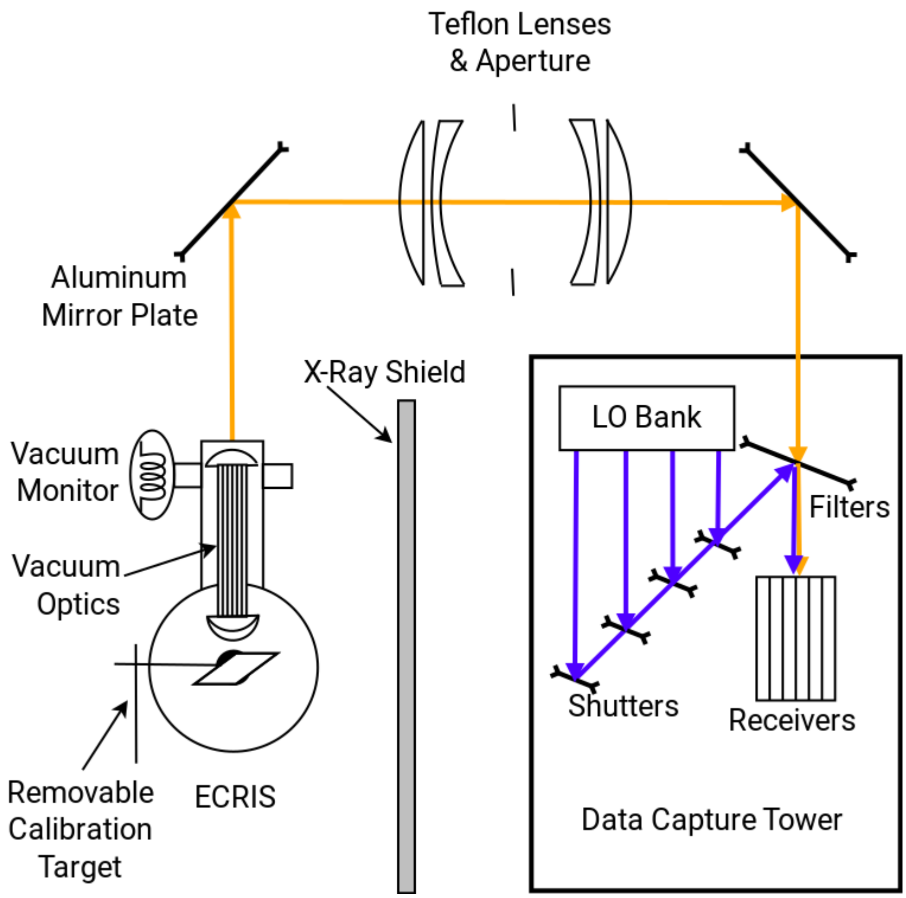

Fig. 2. New Optical Layout.

The ECE detector channel architecture has been made more practical. Each detector pixel will now be made independent by using more frequency step-down stages and readily available 250 MS/s Analog-to-Digital Converters (ADC). The detector channels will be driven by central controllers: Power supplies and timing signals will be supplied via daisy-chains, and the local oscillator signals will be supplied by a switched fanout board. Due to sheer data volume, samples acquired by each ADC will be routed to the data capture computer over a dedicated USB 3 connection.

Based on prototyping experience, it was determined that the non-vacuum optics should be mounted with 3D-printed plastic hardware. This simplifies manufacturing for many parts, but more importantly the use of plastic parts will greatly reduce ECE signal interference due to paraxial reflections.

The immediate future plan for this project is to fabricate and test components as rapidly as possible. Each component for the ECE imaging system, including each lens and EVRS, needs to be characterized across the full design band at various angles of incidence before final assembly integration. A turntable test stand is being built for this purpose. Interactions between components that are difficult to simulate accurately, such as the interaction between stacked EVRS, will be checked experimentally on the turntable as well.