Development of an electron cyclotron emission imaging system

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The electron cyclotron emission imaging system for the Cyclotron Institute's electron cyclotron resonance ion sources (ECRIS) is actively being assembled. The current state of the receiver tower, which houses the electronics for the system, and the receiver cage, which houses the antennas and many of the optical elements, is shown in Fig. 1. The mechanical design and construction is largely complete, and the optical elements and custom electronics will be finalized and fabricated in the coming weeks.

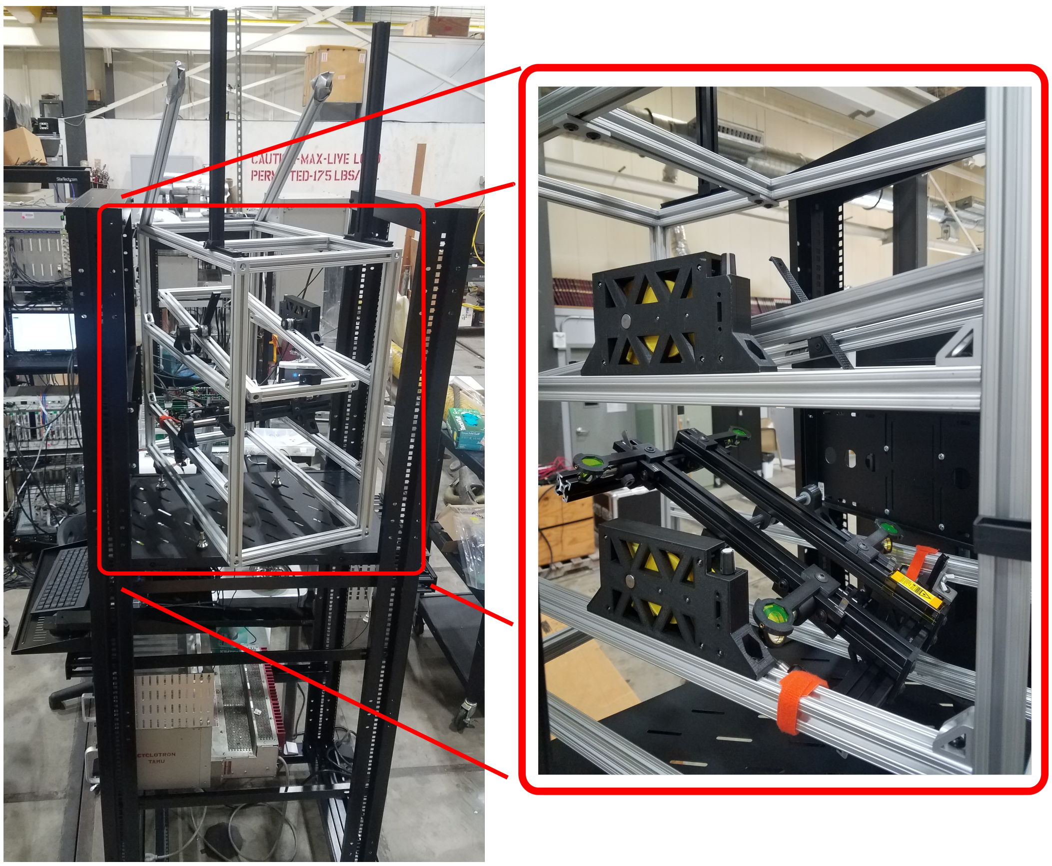

Fig. 1. The receiver cage sitting on its platform in the receiver tower, which houses the support electronics. The inset shows the 3D-printed gearboxes supporting the frames which will mount the beamsplitters and receiver antennas

It was found necessary to revisit the design of the primary optic, which was originally designed by a fastest descent algorithm that iteratively ran 2D full-wave electromagnetic simulations using the MEEP package. Those simulations did not adequately predict the interaction of the optics with the waveguides, and it recently became possible to specify aspheric lens surfaces as a custom geometry within MEEP. Combined with an improved design pipeline, with a new paraxial calculation Python code and ray-tracing in BEAM4, the new 3D MEEP simulations give a much more accurate prediction of diffraction and interference effects.

The new optical design pipeline made it possible to find a single aspherical alumina lens (Fig. 2a) that can replace the five-layer alumina and teflon spherical lens stack of the previous primary optic design. This is not without trade-offs, as the new design has a lower numerical aperture, but fabrication and assembly will be much easier with the new design. The transmitivity of the single lens also varies relatively smoothly with frequency, unlike the old design.

(a) (b)

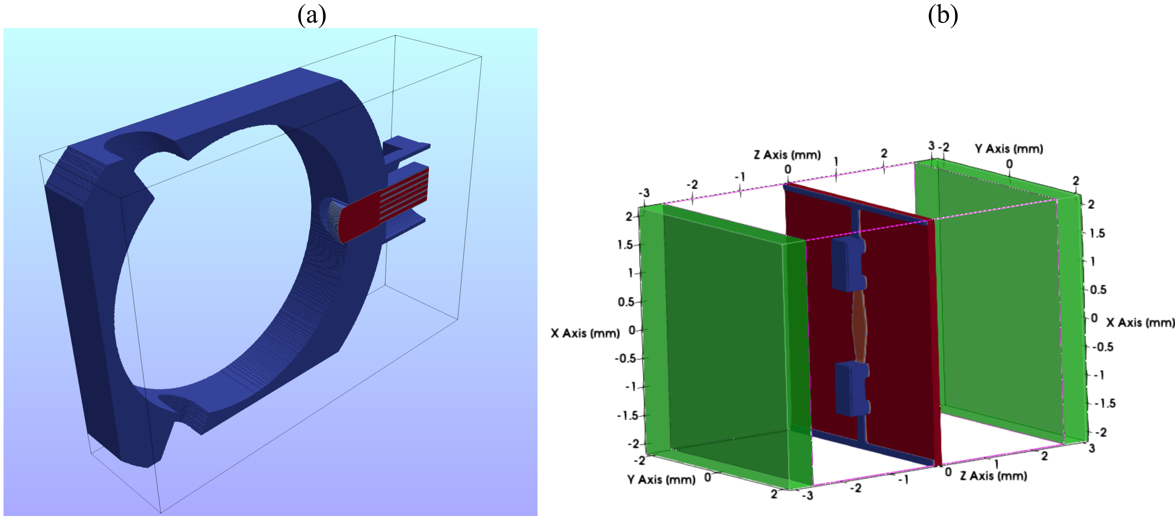

Fig. 2. Paraview renderings of the MEEP simulation geometries for (a) a cutaway of the plasma chamber with the primary optics and (b) the EVRS unit cell. Electromagnetic absorbers along the simulation domain boundaries are omitted from (a) since they line all sides of that simualtion, but the absorbers for (b) are shown in green.

The design of the electronically variable reflective surfaces (EVRS) has also been improved over the past year. Numerous unwanted resonances and couplings were found and explained, leading to a revised unit cell that is much simpler than before. Our anechoic test chamber will be used to verify if the frequency response of prototypes of the new design match simulations, and if they do match the prototypes can be used as the beamsplitter elements in the receiver cage.

The overall electronics scheme and timing sequence for camera operation has been worked out and most of the off-the-shelf components (such as the spectrum analyzers) have been acquired. Once the remaining custom electronics (like the EVRS control boards) have been fabricated, all of the electronics will be integrated in the receiver tower with the data acquisition computer.