TECHNOLOGY BRIEF

NEXT STEP FUSION

On-Chip ECE Radiometer for Electron Temperature Profiles

A compact, system-on-chip electron cyclotron emission (ECE) diagnostic for magnetic confinement fusion (MCF) devices — deployable standalone or combined with a profile reflectometer in a single modular port-plug unit, with frequency coverage tailored to your machine.

THE MEASUREMENT

Electron cyclotron emission radiometry is the workhorse electron temperature diagnostic of magnetically confined plasmas: electrons emit at harmonics of the cyclotron frequency, and since that frequency maps directly to the magnetic field, every received frequency corresponds to a known radial location. A calibrated radiometer thus delivers localized, absolute electron temperature profiles — continuously and in real time, ready for plasma control. Our system targets 100 μs temporal resolution and a standalone absolute calibration, with no dependence on other diagnostics.

THE TECHNOLOGY

The receiver front end builds on millimeter-wave system-on-chip technology developed with UC Davis — the technology behind the ECE imaging system that has operated on DIII-D maintenance-free for seven years [1]:

- **High sensitivity** — over 30 dB gain on chip, detectable power down to 0.1 nW [1].
- **Radically compact** — a 3.4 mm × 3.4 mm receiver chip; 120 channels of the DIII-D imaging system fit in a single rack [1].
- **A full chip family** — V-, W-, F- and G-band designs spanning 50–220 GHz, covering devices up to 6 T [2].
- **A power-plant path** — radiation-hardened GaN chip versions have been tested for high-neutron environments [2].

ONE HARDWARE CORE, TWO TOKAMAKS

Our prototype is designed for two machines at once: DIII-D (2.0 T) and TCV (1.4 T). The same on-chip core covers both — roughly 85–108 GHz with 16 channels on DIII-D and 60–80 GHz on TCV — with the band selection driven by each device's magnetic field. The design is supported end-to-end by synthetic diagnostics using the TRAVIS ray-tracing code [3], and will be validated against each machine's existing ECE and Thomson scattering systems. Plasma testing is planned on TCV in late 2026 and on DIII-D in early 2027.

FROM PROTOTYPE TO YOUR DEVICE

T_e and n_e from one port — the ECE radiometer shares a single port plug, power supply and protection with our profile reflectometer, delivering two core kinetic profiles from one compact, space-saving unit.

Integrated or fully standalone — the modular architecture means the ECE radiometer can be delivered on its own, with further modules added later without redesign or disruption to the installed system.

Customized for machine — frequency plan, channel count, antennas, and port geometry are derived from your field, density and access constraints, as done for DIII-D/TCV; the same approach extends beyond 300 GHz.

Industrial delivery — unified data acquisition, calibration and control software across all modules, backed by a controlled supply chain with off-the-shelf parts and replacement units for minimal downtime.

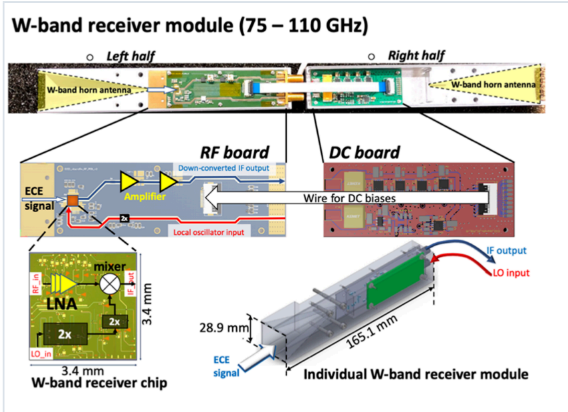

Fig. 1. W-band (75–110 GHz) on-chip receiver module developed by UC Davis: the 3.4 mm receiver chip, RF and DC boards, and the assembled module [1].

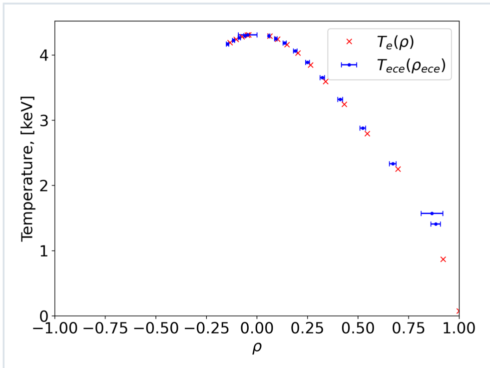

Fig. 2. Synthetic ECE validation for a DIII-D reference discharge: the simulated radiometer measurement (blue) reproduces the model electron temperature profile (red) across the covered radii [3].

MODULAR DIAGNOSTICS PLATFORM

This radiometer is a module of the **Modular Diagnostics Platform (MDP)** — Next Step Fusion's port-plug-integrated microwave diagnostic solution for next-generation MCF devices and future fusion power plants.

The MDP minimizes in-vessel footprint through **shared antennas and transmission lines**, uses maintainable, standardized modules, and employs physics-informed models to reconstruct plasma parameters beyond what is directly measured.

REFERENCES

1. Y. Zhu et al., "W-band system-on-chip electron cyclotron emission imaging system on DIII-D," Rev. Sci. Instrum. 91, 093504 (2020), doi: 10.1063/5.0022057.
2. A. Sirinelli, G. Subbotin, M. Nurgaliev, Y. Zhu, "On-Chip Microwave Diagnostics for Fusion Power Plants," International Reflectometry Workshop, 2026.
3. N. B. Marushchenko, Y. Turkin, H. Maassberg, "Ray-tracing code TRAVIS for ECR heating, EC current drive and ECE diagnostic," Comput. Phys. Commun. 185, 165–176 (2014), doi: 10.1016/j.cpc.2013.09.002.

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Planning temperature diagnostics for your device?
Talk to us at the design stage.