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CVD Diamond Detectors for Fast UV and SX-Ray Diagnostics on FTU

F. BOMBARDA[1], M. ANGELONE[1], G. APRUZZESE[1], C. CENTIOLI[1], S. CESARONI[2], L. GABELLIERI[1,3], A. GROSSO[1], M. MARINELLI[2], E. MILANI[2], S. PALOMBA[2], V. PIERGOTTI[1], G. PUCELLA[1], G. ROCCHI[1], A. ROMANO[1,3], A. SIBIO[1], B. TILIA[1], C. VERONA[2], G. VERONA-RINATI[2]

[1]*ENEA, Fusion and Nuclear Safety Department, Frascati (Rome), Italy*

[2]*Dept. of Industrial Engineering, Università di Roma "Tor Vergata," Rome, Italy*

[3]*Presently DTT S.c.a.r.l., Frascati (Rome), Italy*

E-mail: francesca.bombarda@enea.it

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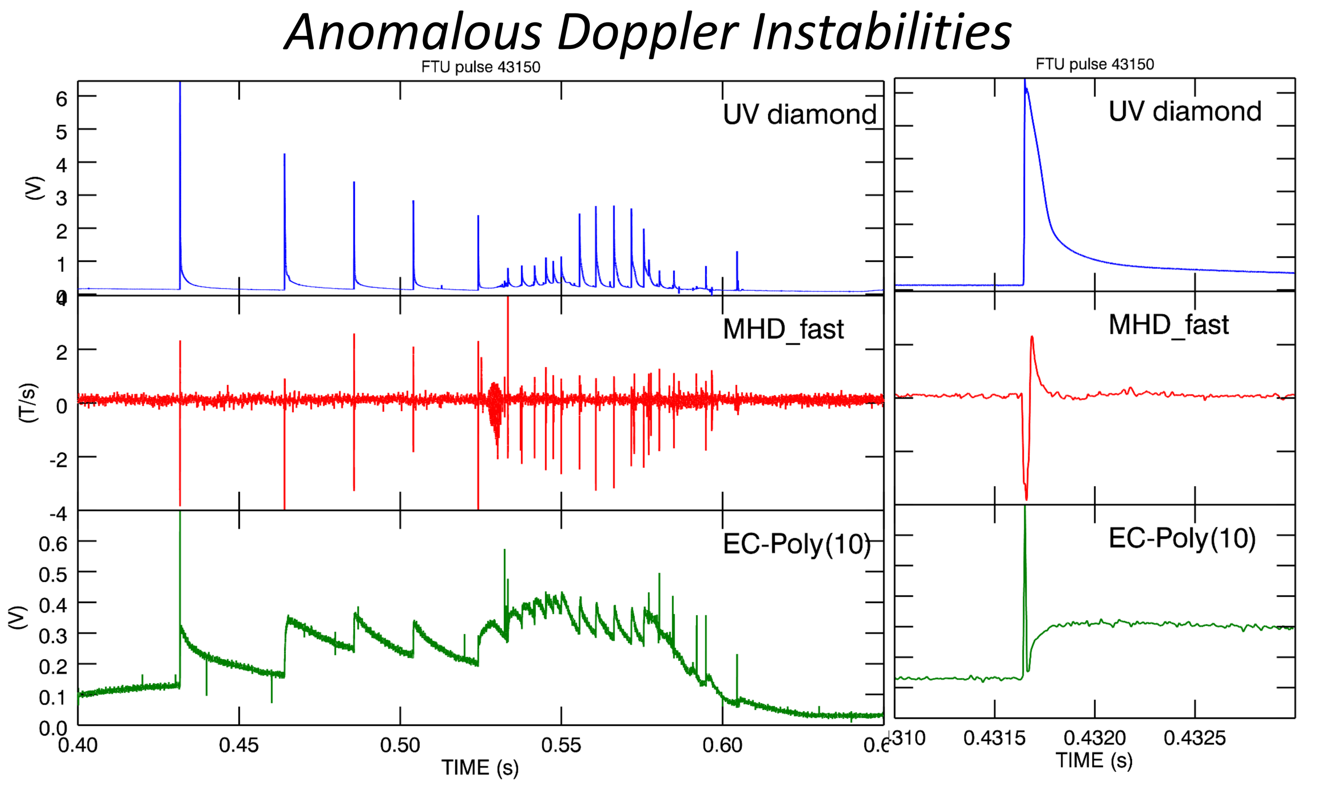
TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA

ABSTRACT

- Photodetectors based on Chemical Vapor Deposition (CVD) single crystal diamonds were installed on FTU . Plasma fast events have been collected in several different plasma conditions, confirming the fast response capabilities of diamond detectors and the high S/N ratio.
- Examples include the observation of the so-called Anomalous Doppler Instabilities in RE beam, fast oscillations in the plasma emission in the presence of tearing modes, pellet ablation processes, MARFEs, ECH power modulation experiments.
- The CVD diamond detectors proved their possible use as replacement of the Si photodiodes currently adopted for Soft X-Ray tomography (SXT) on future devices with harsher radiation environments, and as a possible complement to conventional bolometers.
- The first encouraging results have prompted launching an R&D program for the development of full-fledged diamond bolometers, which will be especially well suited for the coverage of the divertor and edge regions in high performance devices, in the energy range from 10 eV to about 20 keV.

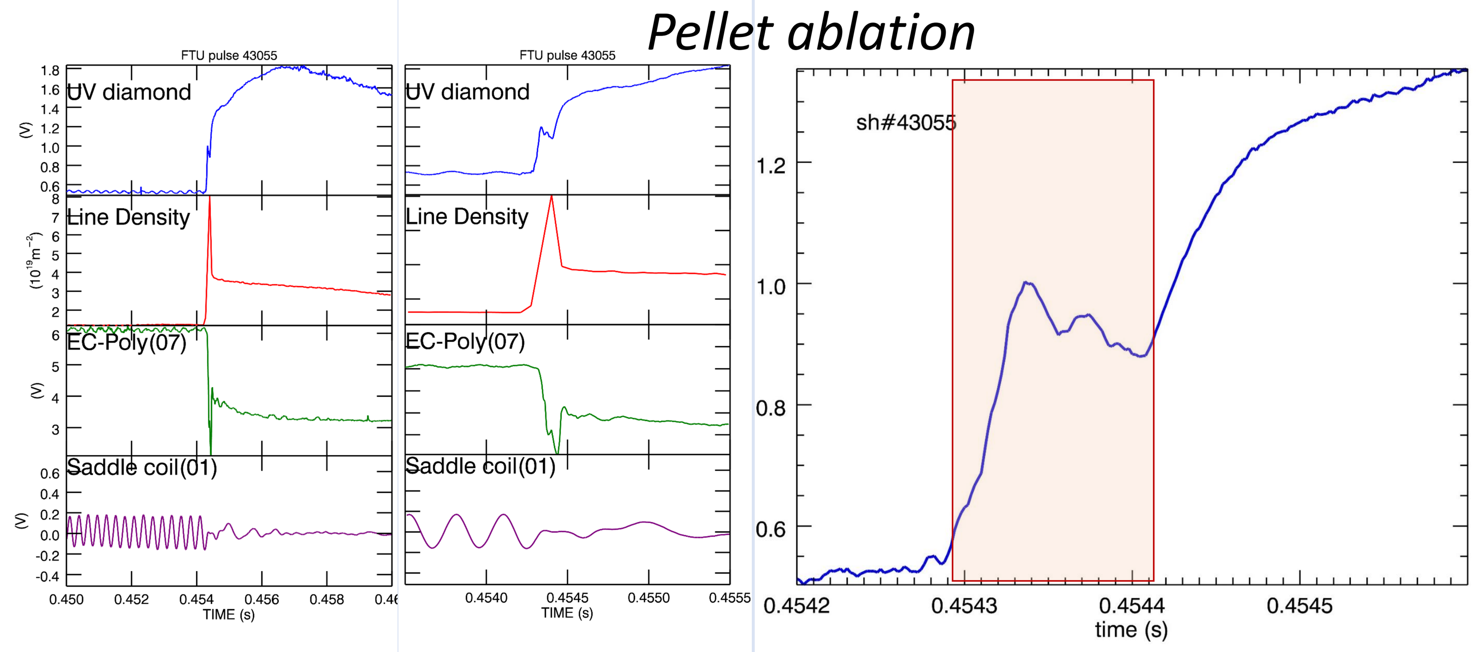
EXPERIMENTAL RESULTS FROM FTU

Anomalous Doppler Instabilities



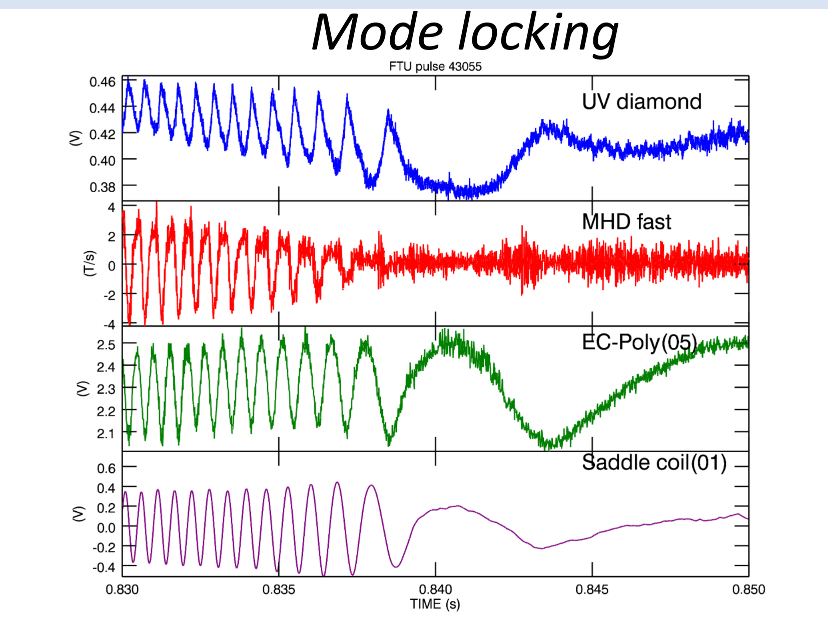
Detection of RE beam induced ADI instabilities by means of the UV detector, compared to the MHD pick-up coil signal and to the suprathermal electron cyclotron emission from a channel of the ECE grating polychromator.

Pellet ablation



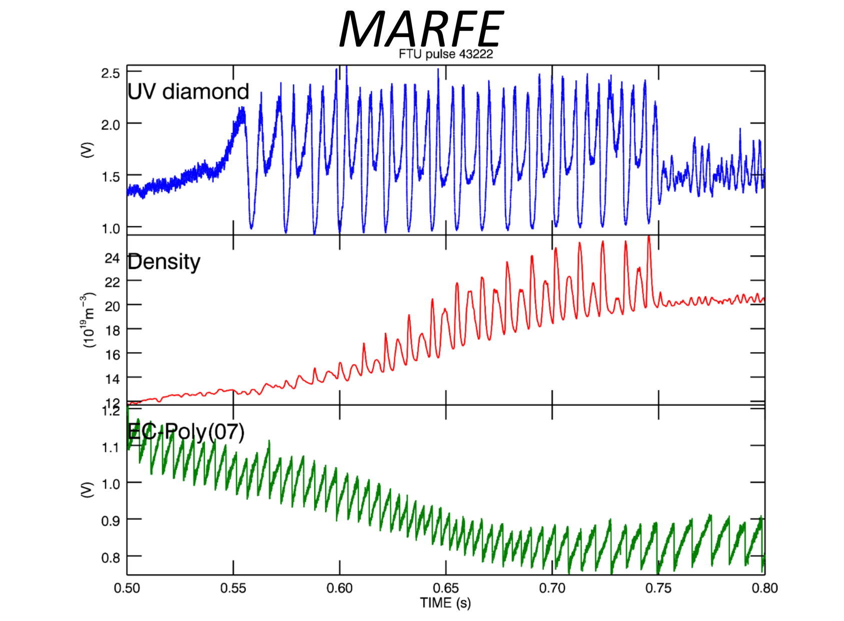
Ablation phase of a D pellet injected at about 1.2 km/s from the low field side midplane. The first column covers 20 ms from the injection trigger of the UV diamond signal, the line average density at R=1.1 m, a core channel of the ECE polychromator, and one of the saddle coils; the second column is an expanded view of the same signals; on the right 0.4 ms of the UV signal with the actual ablation phase occurring during the shaded area.

Mode locking



Example of rotating 2/1 tearing mode slowing down and locking as seen by different fast diagnostics. From the top: the UV diamond detector, a pick-up coil, a mid-radius channel of the ECE polychromator, and a saddle coil.

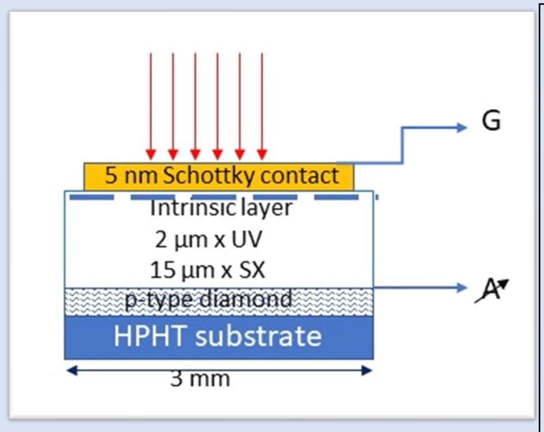
MARFE



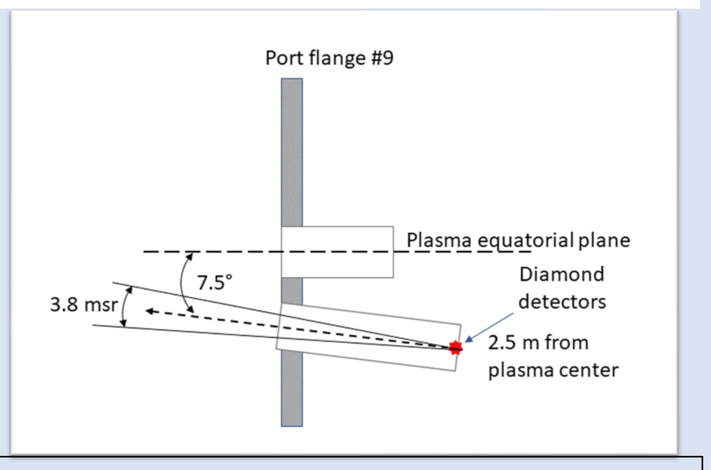
MARFE oscillations as observed by the UV diamond, the line average density measured by the vertical central chord of the interferometer, and a central ECE polychromator channel.

CHARACTERISTICS OF CVD DIAMOND DETECTORS INSTALLED ON FTU

- The CVD diamond detectors installed on FTU for SX and UV diagnostics were developed and grown at "Tor Vergata" University in a p-type/intrinsic/Schottky metal contact configuration.
- Diamonds operate at room temperature with no external applied voltage (thanks to the Schottky barrier, about 1-1.5 V), or with an external bias (< 10 V)
- They were operated in current mode with low-noise current preamplifiers as front-end electronics, which allowed acquisition rates up to 500 kHz. Typical transimpedance gains of $10^5 - 10^7$ V/A were used, providing excellent signal-to-noise ratios.

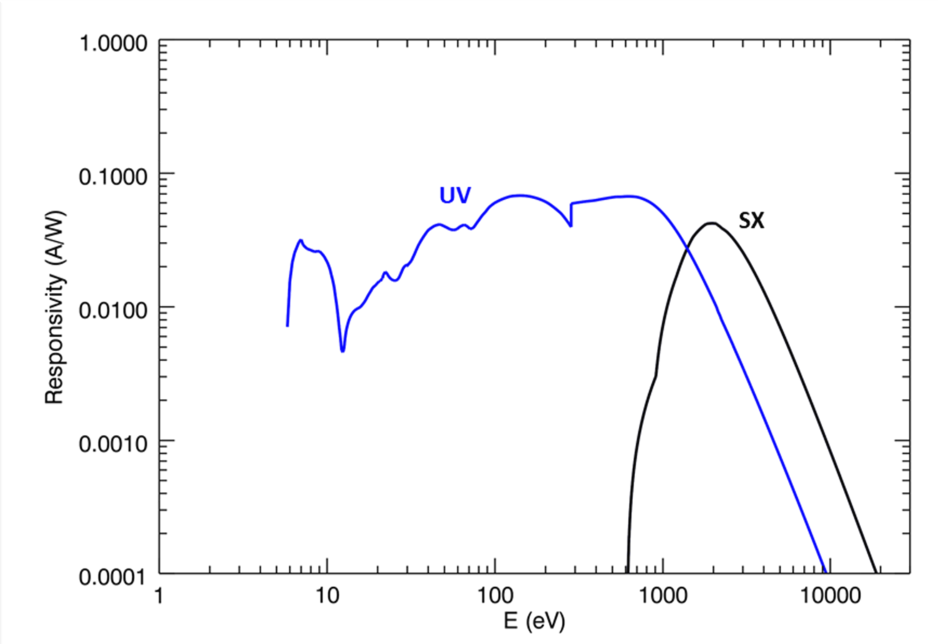


Metal/intrinsic/p-type CVD diamond detectors: the collected current measures the power flux deposited into the detector across the contact surface



Schematic of the viewing geometry.

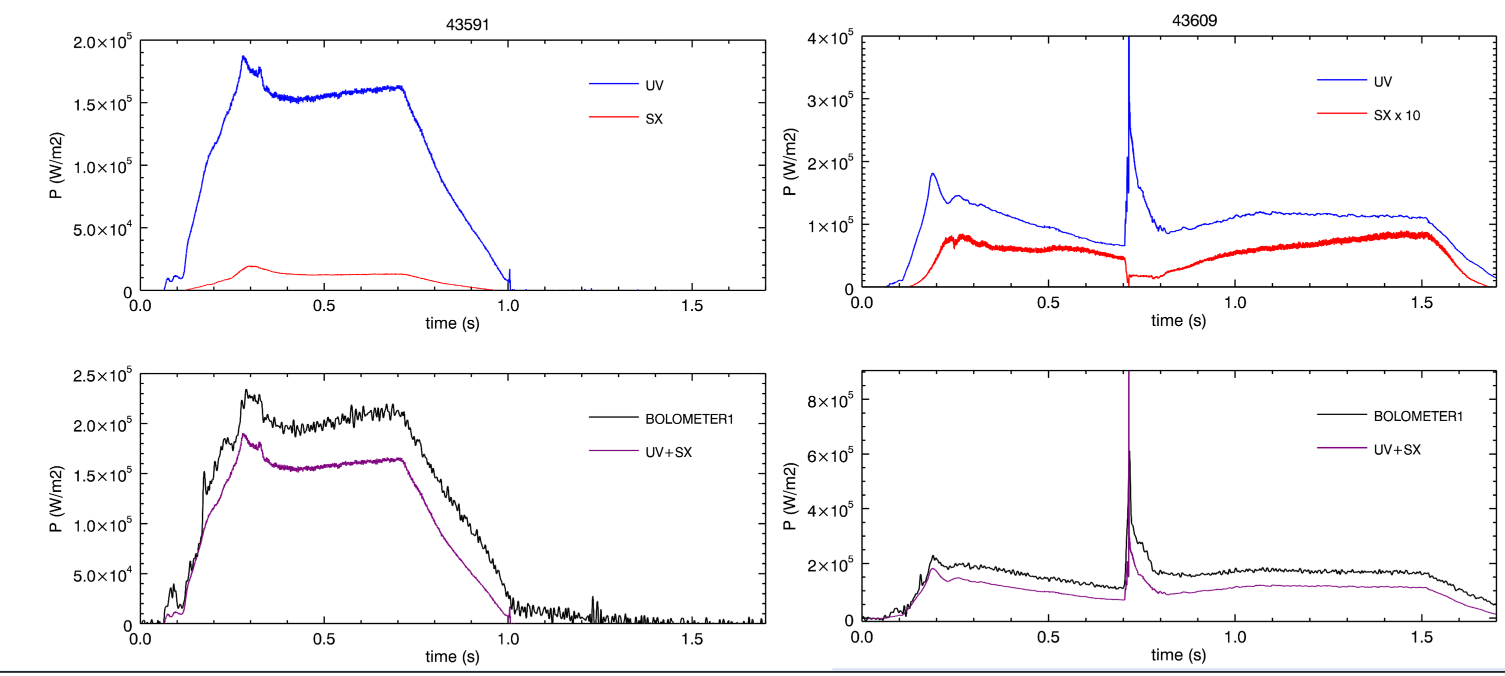
Calculated Responsivity curves



The responsivity curves are calculated from tabulated atomic scattering factors above 30 eV and from refractive index data below it; the calculation includes 5 nm of "dead" layer, the Pt and Cr 5 nm contact layers, and the 6 mm Mylar filter for the SX detector. Similar cases have been verified experimentally and found in excellent agreement.

CVD DIAMOND-BASED BOLOMETRY

- The comparison with a bolometer channel having a similar LOS shows a pretty good agreement in the early phase of the discharge, when the plasma is still relatively cold, and a systematic underestimate of the emitted power density when the plasma temperature exceeds about 1 keV, as expected, despite the lack of proper calibration of the diamonds.
- These encouraging results have prompted launching an R&D program for the development of full-fledged diamond bolometers.



Comparison of radiated power densities from one of the calibrated bolometer channels and the combined signals from the UV and SX diamonds for two FTU discharges: a standard Ohmic discharge at 5 T, 550 kA, $n_e=5\times10^{19}m^{-3}$ (left), and one at 5 T, 360 kA, $n_e=1.3\times10^{19}m^{-3}$ with a single pellet injection (right). The top plots show the time traces of the two diamond detectors UV and SX, the bottom ones the comparison of their sum with the bolometer channel with a similar line-of-sight.

CONCLUSIONS

The experience on FTU shows that photodectors based on CVD single diamond are especially suitable for:

I. UV and SX tomography/bolometry arrays systems;
II. low energy detectors to monitor fast events occurring at the plasma edge (ELMs, MARFEs, PWI..);
III. identification and rotation velocity of MHD instabilities in the plasma core;
IV. pellet ablation diagnostics.