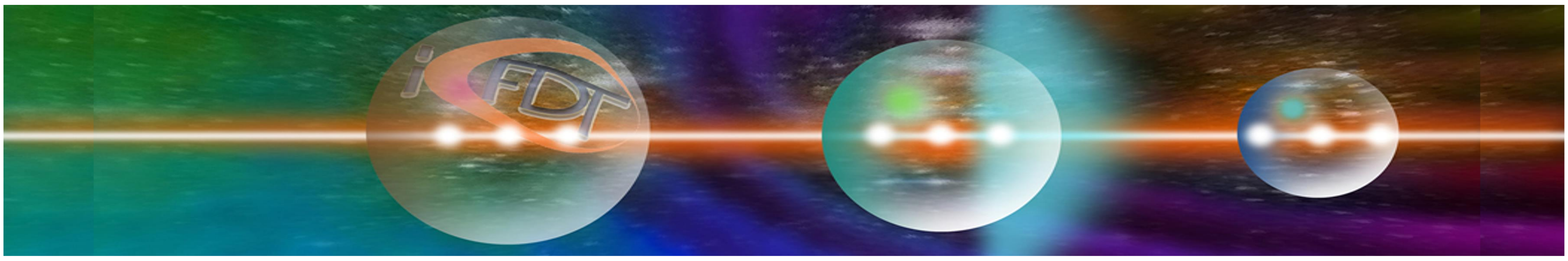

Development of CVD diamond-based photodiodes for UV and SX-rays detection

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Introduction

The well-known physical properties of Chemical Vapor Deposition (CVD) diamonds have made them highly attractive for use as detectors in harsh environments characterized by high irradiation levels, such as those found in fusion machines **[1]**. Notably, their good radiation hardness, visible wavelength blindness, high carriers' mobility, and high signal-to-noise ratio (S/N) make diamond a promising alternative to the employment of conventional silicon diodes for plasma diagnostics.

In recent years, the Department of Industrial Engineering of "Tor Vergata" University of Rome has conducted extensive research on the development of photodiodes based on high-purity thin diamond layers (5÷50 μm of thickness) for the detection of UV and Soft-X rays (**Fig. 1**). In order to meet the requirements that detectors should have to be installed in tomography systems for fusion plasma diagnostics, the study focused on two main detector layouts: the "layered layout" and the "LAT layout" **[2]**.

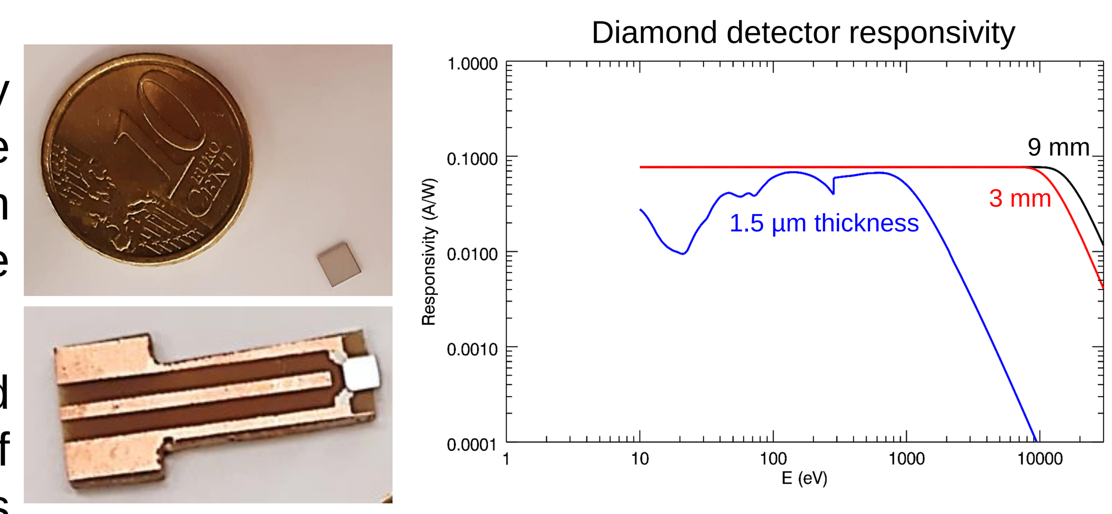
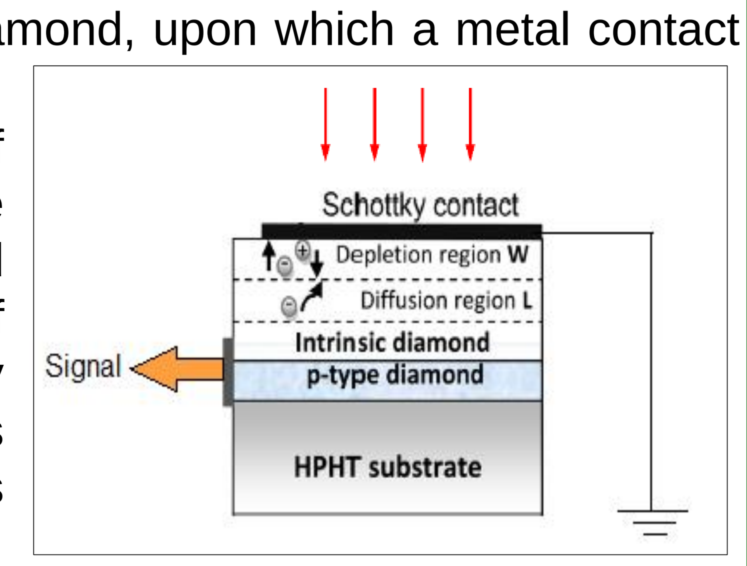


***Figure 1**: Pictures of a CVD diamond layer and example of detector layout (left), and calculation of the approximated detector's responsivity to photons of different energies for various diamond active layer thicknesses (right) **[2]**.*

Layered layout diamond detector

The CVD diamond photodetector in layered layout allows the detection of photons with energies ranging from 5.5 eV to 2-3 keV. The device features a layered structure of p-type/intrinsic CVD diamond, upon which a metal contact is deposited in order to establish a Schottky internal junction (**Fig. 2 top**). This kind of detectors has already been installed inside tokamaks such as FTU (**Fig. 2 bottom**) and JET, obtaining excellent results in terms of performance and reliability **[3, 4]**. The very fast response of diamond photodetectors (below 1 ns) allowed to study fast events occurred in different plasma conditions.



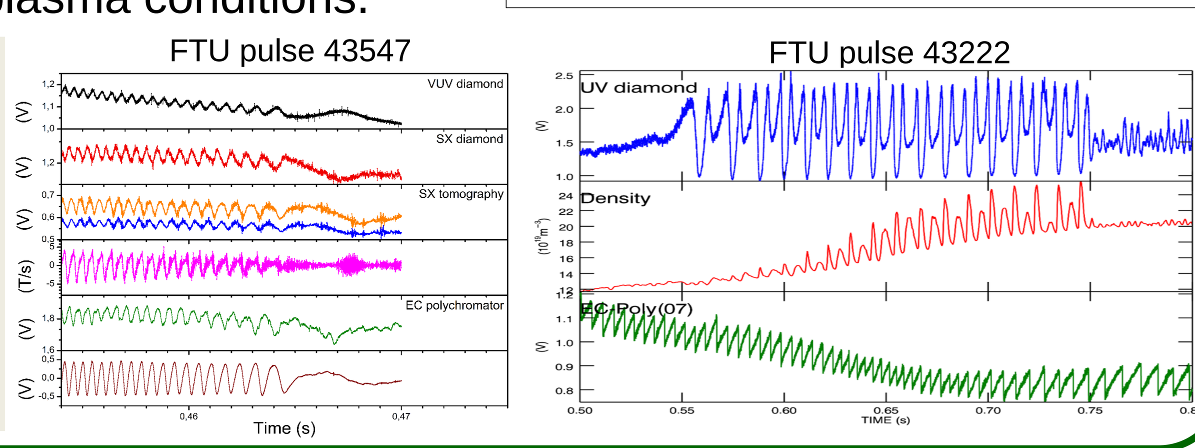


***Figure 2**: Structure of the diamond photodetector in layered layout (top), and some events detected by diamonds on FTU (bottom). In this case, diamond signals are compared to machine diagnostics: MHD activity (bottom left) and MARFE (bottom right) are clearly recognizable **[3]**.*

LAT layout diamond detector

The CVD diamond photodetector in LAT layout foresees the lateral irradiation of the diamond layer, allowing the detection of photons with energies higher than 5 keV **[2]**. Two diamonds in layered structure (**Fig. 3 top**) are coupled through a metal contact deposited upon each layer, and the assembly is incorporated in an epoxy resin matrix to form a single detector. This device has been successfully tested under X-rays irradiation up to 50 keV (**Fig. 3 bottom**).

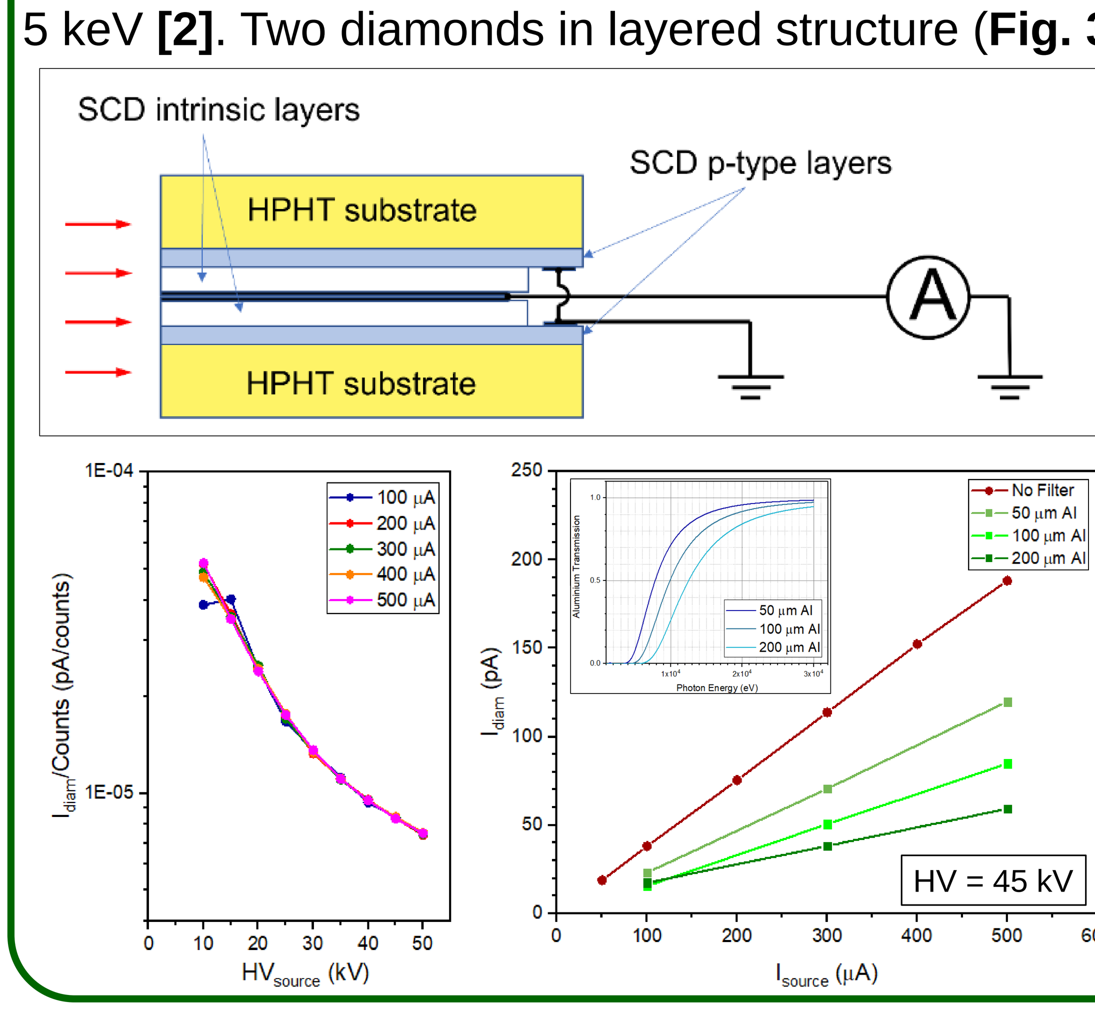


***Figure 3**: Scheme of the diamond detector in LAT layout (top), detector response normalized on the integral of X-rays source emission spectra as a function of the source HV for different source strength (bottom left) and comparison between detector's signal with and without Aluminium filters of different thicknesses in front of the X-rays source (bottom right) **[2]**.*

Multi-channel amplifier prototype

Tomographic systems based on diamond photodiodes are currently being designed for two fusion machines under construction, the Divertor Tokamak Test (DTT) in Italy **[5]** and SPARC in US **[6]**. These systems involve ~10^2 detectors arranged along specific lines-of-sight to fully cover the poloidal cross section of the plasma. For such a large number of detectors, a new 8-channels low-noise current amplifier was specifically developed by CAEN, and a first compact prototype was released for preliminary testing (**Fig. 4**). **Table 1** presents the main features of the prototype, whose parameters are all remotely programmable.

Tests were conducted using a layered layout diamond detector irradiated with a X-rays source (E_{max}=30 keV). The 8 amplifier channels have been independently tested using no bias, 10^8 gain, and 15 kHz bandwidth. All channels exhibited an offset of ~1±3 mV. During measurements under irradiation, the S/N~150 confirmed the already observed excellent capabilities of the diamond detector.

***Figure 4**: The new 8-channel low-noise current amplifier prototype developed by CAEN.*

***Table 1**: Key features of the CAEN amplifier prototype for the CVD diamond-based photodiodes operation.*

Characteristics of the Differential Input Low noise Transimpedence Amplifier	
# independent channels	8
Transimpedence range (Gain)	From 10^3 to 10^9
Bandwidth	From 15 kHz to 1 MHz
Max input biasing voltage	10 V
Differential input configuration with a CMRR > 80 dB	
Programmable 1 kHz low pass filter	
Electric discharges input protection	

Conclusions and future work

CVD diamond-based photodiodes for UV and SX-rays detection have been developed by "Tor Vergata" University of Rome in two different layouts (i.e. layered and LAT). Given the encouraging experimental results, tomographic systems based on these devices are under design for DTT and SPARC. Next studies involve measurements using calibrated monochromatic sources at a synchrotron facility, and the installation of a diamond detector array on an operating tokamak. These tests will further assess the features of the new CAEN amplifier for the simultaneously operation of 8 diamond detectors.

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