M2 internship project: large scale rectennas for short wavelength infrared (SWIR) detection and imagery

LTM, Grenoble, FRANCE (collab. IM2NP, Marseille)

a) Project's context and objectives

Short-wave infrared (SWIR) photodetection (0.9–2.7 μm) is critical for night vision, remote sensing, and high-speed communications. Commercially established platforms rely on semiconductor photodiodes using indium gallium arsenide (InGaAs) or mercury cadmium telluride (HgCdTe) (Fig. 1A). Despite their maturity, these materials face severe bottlenecks, including toxic precursors, scarce constituent elements, and cost-prohibitive epitaxial fabrication. In contrast, optical nano-rectennas present a CMOS-compatible framework by integrating plasmonic nano-antennas with ultrafast wave-rectification mechanism eliminates semiconductor bandgap constraints, enabling broad spectral tunability across the SWIR regime purely through geometric antenna design.

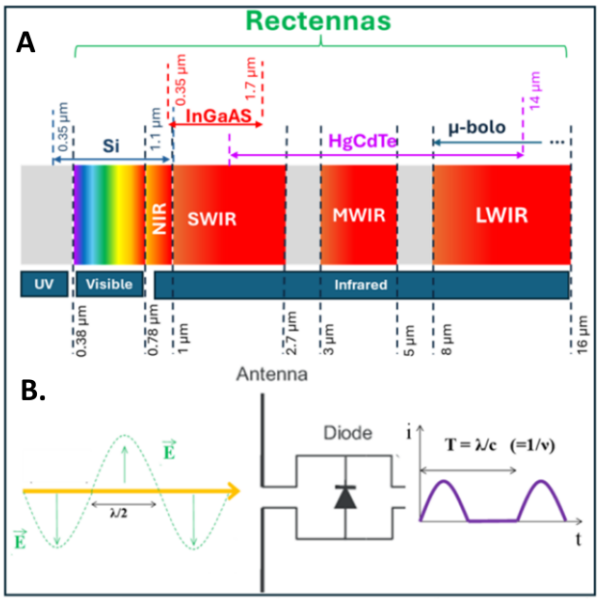


Figure 1. (A.) working spectral ranges of different photodetection technologies and (B.) block diagram of a rectenna

Regarding the rectifying element, metal–insulator–metal (MIM) diodes are among the most promising solutions for ultrahigh-frequency applications (~10^{15} Hz, e.g., SWIR), as extensively reported in the literature[1–3]. A key challenge for optimal energy transfer is achieving impedance matching between the antenna and diode[4]. To address this, the IM2NP lab (Marseille, France) developed a fully vertically integrated rectenna architecture (Fig. 2A), wherein ultrahigh-frequency diodes are embedded within the plasmonic cavity of a patch nanoantenna, sandwiched between metallic nanocubes (NCs) and a metallic plane[5–6]. This design ensures optimal impedance matching, significantly reducing electrical losses compared to conventional rectennas—where the antenna and diode are fabricated separately and connected via transmission lines[7–8].

However, a critical limitation persists, all reported photoelectrical responses of optical rectennas have been measured only at the nanoscale (e.g., via conductive atomic force microscopy, C-AFM)[2–5]. **To date, no large-area optical rectenna integrated into a functional device has been demonstrated. Bridging this gap is the primary goal of this internship project (where a PhD opportunity for this subject is also being considered, through the école doctorale funding selection or Labex microelectronics).**

b) Methodology to reach the scientific objectives

To reach this objective, the idea is to further combine the nanofabrication capabilities of LTM in Grenoble with the experience on rectennas of the IN2MP lab in Marseille:

Antenna design: Large areas patch nano-antennas able to couple guided plasmonic modes in nano-cavities in SWIR will be developed thanks to recent advances in **bottom-up low-cost high-resolution nanolithography**. The bottom-up nanofabrication technique, a block copolymer self-assembly, will be used to fabricate 'fingerprint' shaped patch nano-antennas exhibiting continuous arrays of lines (typical lines dimensions of 40 nm) oriented in different directions (Fig. 2C). Such a structure allows for

harvesting light independently to the light polarization, with the advantage of producing both the antenna and the upper contact electrode in the same technological step.

High frequency diodes: Optimization of ultra-thin dielectrics by atomic layer deposition (ALD) deposition for ultra-fast MIM tunneling diodes (Fig. 2D). This technology exhibits the highest working frequency to be used in rectenna devices[1,2,6].

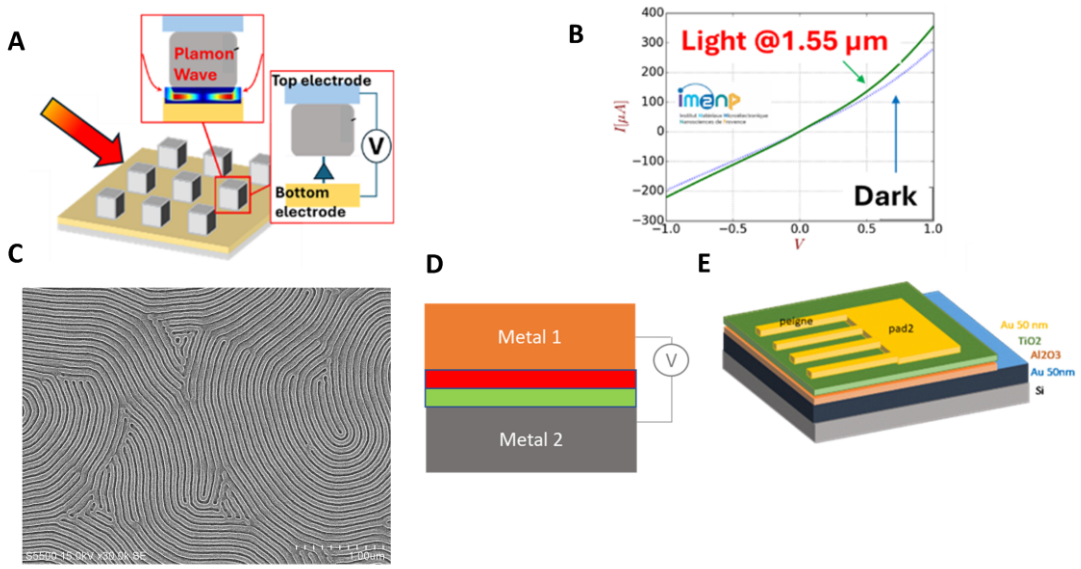


Figure 2. (A) Rectenna architecture (IM2NP Marseille), (B) its photoelectrical response[6], (C) a 40 nm polymer lines (fingerprint pattern) made by self-assembly of block copolymers, (D) a metal-insulator-metal (MIM) diode scheme, and (E) an integrated nano-antennas/diodes scheme.

Optical simulation: In parallel, finite-difference time-domain (FDTD) simulations using Ansys Lumerical software will be conducted to predict and corroborate the experimental results, specifically to verify the resonance wavelength.

Nano-antennas/diodes electrical connection: Finally, the diodes will be integrated to the plasmonic nano-cavity of patch nano-antennas to directly rectify the vertical motion of electrons induced by plasmonic waves. Such vertical architecture (Fig. 2E) where the top patch and the bottom metallic plain also play the role of electrodes for MIM, is the most performant architecture today[1,2,6]. The goal is here to combine these MIM structures with the large scale nanoresonator arrays.

We are looking for an enthusiastic 2nd-year Master's student with a background in Optics, Photonics, Physics, Nanotechnology, Materials Science, or related disciplines to join our team. To apply, please send your cover letter and curriculum vitae (including the final grades from your previous studies and contact details for at least one reference) to:

c) Contacts (please send your application to these two emails)

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d) References

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