The University of Queensland - IIT Delhi Academy of Research Joint PhD Project

Project title	**Non-destructive THz Imaging to Study the Viability of Green Materials for Construction**
Project code	**UQIDAR 00220**
Project description	One of the crucial climate mitigation strategies is to replace energy and CO2 intensive building materials, such as cement, asphalt etc. by more biophilic materials, such as, timber, clay, stones etc. However, these 'green' construction materials, even with extensive conditioning are prone to fungal growth and water inclusion damage that ultimately limits their widespread use in many critical structures. Hence, a non-destructive characterization technique which could probe these materials at sub-surface level to detect the damage and study the underlying dynamics of these factors inside the material would be of immense help. THz spectroscopy has already been employed in studying fungal growth in wood, water porosity in stones etc.; however, a more comprehensive study is required, supported by theoretical modelling and framework to understand the correlation between the observed damage in these materials and the recent events of extreme weather pattern. This project will explore spectroscopy and imaging using terahertz (THz) range (3000 “ 30 Âµm in wavelength or 0.1 Ã— 1012 “ 10 Ã— 1012 Hz in frequency) which is an extremely sensitive non-contact, non-invasive technique to measure hydration levels and even the presence of fungi. When the material is non-conductive, like wood, clay and various forms of stones like Marble, THz can penetrate the surface of such material and can gather structural anomaly, like cracks, in the volume of the material. Several locally available and branded green construction materials will be studied and their responses will be calibrated using a PCA based CW-THz spectroscopy and imaging set-up at IIT Delhi on the macroscale, as well as being investigated on the nanoscale using a THz s-SNOM at UQ. These investigations will inform the development of a comprehensive analytical model to interpret the THz response of these materials. In the second phase at UQ, QCL-based high power THz sources working in a relatively narrow frequency range will be used to target the high-frequency response of these materials.
Project outcomes	This programme will continue with the very successful collaboration between the two groups at IIT Delhi and University of Queensland. The above project will utilize the unique combination of expertise and facilities at two internationally-leading research groups to develop an innovative technology targeting the applications of THz radiation in civil engineering and construction. Furthermore, by leveraging the world-class expertise in developing THz lasers and time domain THz imaging systems at both UQ and IIT-D , we will develop a novel terahertz (THz) frequency based diagnostic tool that will provide an objective and non-contact means of diagnostics of both surface and sub-surface damage in building materials. There is potential for significant economic and societal impact through the translation of these technologies to industry, the licensing for manufacture by Indian and Australian industries, and through the creation and growth of THz and optical sensing companies. Both IITD and UQ have a strong track record of industrial collaboration, protecting and licensing IP, and marketing of technologies. Rakic group at UQ is undeniably one of the premier research groups in laser-feedback interferometry worldwide, with a numerous research ˜world-firsts' in LFI sensors and a close working relationship with L3 Micreo Ltd, a subsidiary of L3 Technologies based in Queensland, Australia. The group also boasts the only dedicated THz QCL facility in Australia, which has been previously supported through ARC grants and the Advance

	Queensland Research Fellowship scheme. Overall this AU$3.8M facility consists of 150 m2 of laboratory space dedicated to LFI sensor development spanning the visible, infrared and THz regions of the spectrum. UQ has also recently invested over AU$1M in a Mid-IR & THz scattering near field microscope (s-SNOM) which allows spectroscopy and imaging on the nanoscale. The IITD THz Imaging and Spectroscopy group is the only group in India, and possibly, in the world, which has in-house access to both a broadband THz system (upto 6 THz), HR CW-THz spectroscopy system (as low as 10 MHz resolution) and an ultrafast optical pump-THz probe system with two different pump lasers (780 nm and readily available frequency doubled 390 nm). This facility is a unique facility in India which is housed in 80 m2 of climate-controlled laboratory space and also houses a state-of-the-art Raman spectrometer for high pressure studies on geological materials. This programme will also generate impact through the creation of a vibrant inter-disciplinary research environment across UQ and IITD sites that will through UQIDAR attract and retain outstanding young researchers who will grow to be future academic and industrial leaders in India and Australia, and advocates in science and engineering. PhD students associated with this programme will visit and work at partner sites for joint experiments, simulations and discussion, leading to the sharing of skills and the dissemination of scientific outcomes to aligned research programmes at these sites. The proposed research will give rise to publications in leading scholarly journals in the fields of photonics and terahertz engineering including Optics Letters, Optics Express, Applied Physics Letters, and IEEE Transactions on Terahertz Science and Technology. We also anticipate communicating our research outcomes at premier international conferences in the field. Additionally, we will promote open access to our research findings, and plan to communicate research results both within and beyond the academic community.
Advisory team	**UQ Principal Supervisor** **Professor Aleksander Rakic** Information Technology and Electrical Engineering adee@eait.uq.edu.au https://researchers.uq.edu.au/researcher/473 **IITD PrincipalSupervisor** **Professor Amartya Sengupta** Physics amartya@physics.iitd.ac.in http://web.iitd.ac.in/~amartya/ **Additional Supervisor(s)** **Dr Aparajita Bandyopadhyay**
Type of student	Applications are open to: I or q students who meet eligibility criteria.
Discipline background of student	Ideally, this project requires students with a background in: Applied Mechanics, Mechanical Engineering, Physics, Electrical Engineering, Civil Engineering, Applied Mathematics
Ideal candidate	**Essential Capabilities:** Excellent programming skills in MATLAB and LABVIEW Experience with AUTOCAD software and machine drawing Excellent English Communication Skills. **Desirable Capabilities:** Understanding of materials and their characteristics Image Processing Experience with MATLAB.

Application process	**Expected qualifications (Courses/Degrees etc.):** MSc/MTech in Physics, Applied Mathematics, Electrical Engineeing, Applied Mechanics, Mechanical Engineering or Civil Engineering. Apply online by the due date: https://www.uqidar.org/students/how-to-apply/