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

Project title	**Application of non-contact THz spectroscopic imaging towards preservation of heritage structures in India**
Project code	**UQIDAR 00219**
Project description	Taj Mahal, the 17th century architectural wonder is known worldwide for its visual appeal in white marble with beautiful inlay works in the style of 'Pietra Dura' (pietra means stone and dura means hard) from Florence, Italy. It has recently come under scrutiny owing to the long-drawn restoration process for structural damage and surface discoloration. The conventional means of structural survey in heritage architectures, like the Taj Mahal, is based mostly on visual assessments by experts which is highly time-consuming and subjective; and in most cases can be done only after the damages become apparent. Consequently, the restoration involves exhaustive repair procedures. In India, many other heritage structures with unique display of craftsmanship are also equally plagued by structural and surface damage where conservationists are looking for an objective and alternate means of diagnostics of such damage. 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 detect water damage, both surface and sub-surface crack formation and even the presence of fungi in these heritage architectures. This project will, therefore, include field work as well as laboratory experiment and data analyses for important heritage and culturally relevant buildings, including the Taj Mahal. Samples closely representing the structural content and artistry of these buildings will be studied as simulants. Project will use a time-domain THz broadband system& and a CW-THz spectroscopy and imaging system for macroscopic interrogation. To explore the samples on the nanoscale project will use THz s-SNOM spectroscopy. Appropriate data analyses will be performed to interpret the THz response of these materials. The project would also involve QCL-based high power THz sources working in a relatively narrow frequency range which will be used to image and model the high-frequency response of the above simulants.
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 the field of heritage science. 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 heritage buildings that are important to India and rest of the world. Conservationists and engineers who are tasked with the restoration of such heritage buildings, where damages are being accelerated by recent deterioration in environmental conditions will also benefit in the field of THz metrology through the use of these fast and sensitive spectroscopic systems. 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 a.rakic@uq.edu.au https://researchers.uq.edu.au/researcher/473 **IITD PrincipalSupervisor** **Professor Amartya Sengupta** Physics amartya@physics.iitd.ac.in 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 **Expected qualifications (Courses/Degrees etc.):** MSc/MTech in Physics, Applied Mathematics, Electrical Engineeing, Applied Mechanics, Mechanical Engineering or Civil Engineering
Application process	Apply online by the due date: https://www.uqidar.org/students/how-to-apply/