विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

MISSION INNOVATION
accelerating the clean energy revolution

DST-IIT Kanpur Integrated Clean Energy Materials Acceleration Platform

A consortium for the Development of Materials and Devices for Energy Harvesting and Conservation Technologies

QUOTES

The Integrated Clean Energy Material Acceleration Platform (MAPs) would bring best minds together and is expected to lead to research and technology outputs of immense value for clean energy driven growth. Maps would also accelerate the pace of material discovery up to 10 times faster in clean energy domain for cost effective, reliable, and robust solutions.

Dr. Jitendra Singh
Union Minister for Science & Technology, Earth Sciences,
Environment, Forests and Climate Change- Government of India

Accelerated discovery of energy materials has the potential to make clean energy harnessing more efficient and affordable. These Material Acceleration platforms would develop materials and energy systems which can address the issues of variability and uncertainty intrinsic to clean energy sources and provide research led disruptive solution.

Dr. Srivari Chandrasekhar
Secretary, Department of Science and Technology
Ministry of Science and Technology – Government of India

Integrated Clean Energy Material Acceleration Platform would leverage emerging capabilities in next-generation computing, artificial intelligence (AI) and machine learning and robotics to accelerate the pace of materials discovery.

Dr. Anita Gupta
Head, TMD (Energy, Water & all others), DST
Ministry of Science and Technology – Government of India

Materials For Energy seeks to accelerate innovation from materials to devices via Material Acceleration Platform (MAPs) by coordination of research support activities, where materials are part of the solution.

Dr. Ranjith Krishna Pai
Scientist, TMD (Energy, Water & all others), DST
Ministry of Science and Technology – Government of India

The primary research emphasis at the center is the development of energy harvesting and conservation materials possessing excellent functional performance and ambient stability. DST-IIT Kanpur center could enable the fast-paced translation and subsequent commercialization of perovskite solar cells, solar thermal receivers, smart windows and thermal insulating tiles.

Prof. Birabar Ranjit Kumar Nanda
Center Lead PI
Indian Institute of Technology Madras

DST-IIT Kanpur center brings together our strengths in solid-state physics, computational materials science, materials synthesis and characterization, device fabrication, machine learning, automation and reliability evaluation to help accelerate the development of techno-commercially viable clean energy technologies.

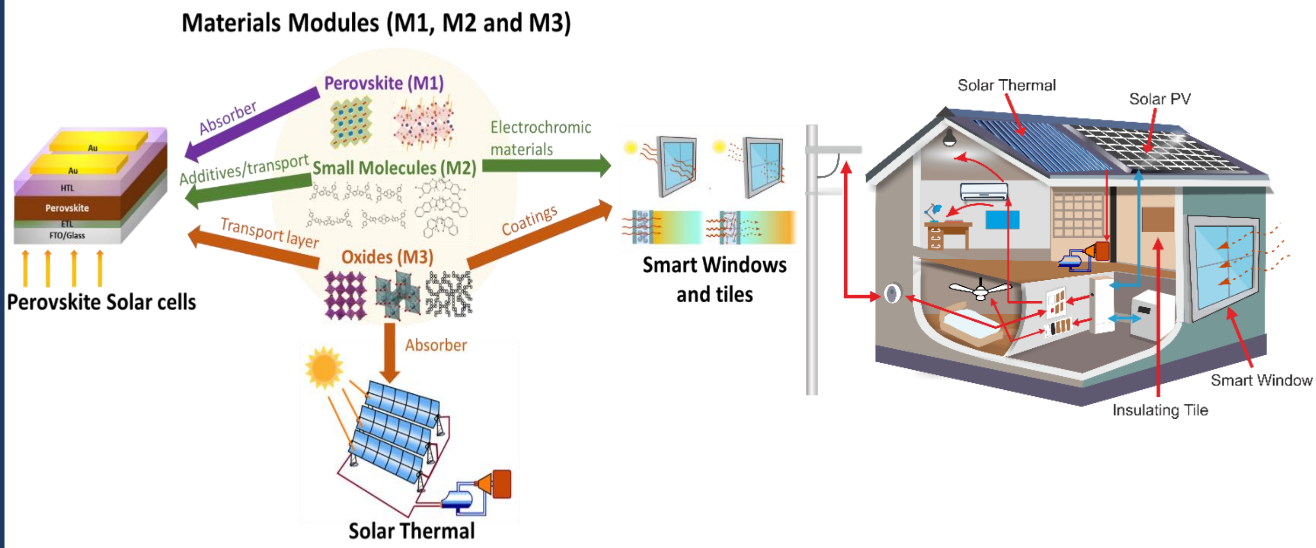
Prof. Kanwar Singh Nalwa
Center Head & Administrative PI
Indian Institute of Technology Kanpur

PREAMBLE

Total energy consumption in India has doubled in a span of 10 years from 620 TWh in 2009 to 1200 TWh in 2019. At the COP26 climate conference in Glasgow (Nov 2021), Prime Minister Modi announced 'Mission 500GW' with aims to take India's renewable energy (RE) capacity to 500GW by the year 2030. Since India's current RE capacity is about 101 GW (2021), we would need to add about 40 GW of RE capacity per year to meet the set goals. The mammoth challenge that we have in front of us can be realized by knowing that the current trajectory of India's RE sector is only about 8GW per year.

As renewable energy production is gaining the spotlight, silicon-based solar photovoltaics are receiving increasing attention as a potentially pervasive approach to sustainable energy generation. However, silicon-based solar cells fabrication is a very high energy-intensive and complex technology, which makes the solar modules costly. The perovskite holds the upper hand over silicon technology for its solution-processed approach resulting in efficiency comparable to silicon cells while using cost effective and facile synthesis and fabrication technology. The ambient stability of the perovskite is the foremost hurdle for the commercialization and new strategies will be developed at the DST_IIT Kanpur center to enhance the stability and performance towards the commercialization of perovskite-based solar cells. India particularly has a high potential to integrate solar energy technology with the smart energy management system which will lead to reduced utilization of conventional energy. Therefore, one of the objectives of the center is to design and develop performance materials for solar thermal systems, and thermal tiles and smart windows for energy-efficient buildings. Such cost-effective and marketable building-integrable technology can leverage the entry of Indian industries into the respective market in line with the 'Make in India', 'Innovate in India' and 'Atmanirbhar Bharat' initiatives of the central government.

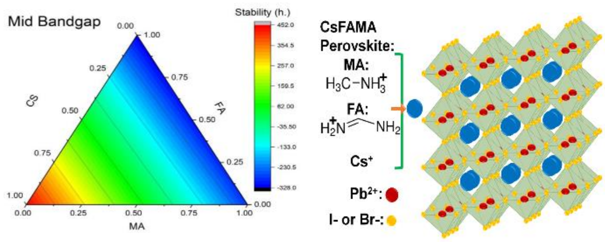
The successful execution at DST-IIT Kanpur CRADMET center is envisaged to deliver critical information on the design and development of new and high-performance materials, solar cells, prototype coatings, smart windows, tiles and solar thermal components and a catalogue of potent materials and device components will be generated over the tenure of the project. Our team comprising of researchers from the IITs (Kanpur, Roorkee, Madras, Guwahati and Hyderabad), CSIR (IICT and NIIST), IIITDM, IISER Thiruvananthapuram, NIT Tiruchirappalli and ARCI Hyderabad, brings in expertise from various facets of energy harvesting and conservation including photovoltaics, solar thermal storage, materials synthesis and characterization, automation, computational materials science and machine learning into a unified synergistic working group. The proposed deliverables of the center can potentially be integrated with numerous clean energy technologies that can be immediately employed by industry, making it versatile in terms of national and global acceptance.

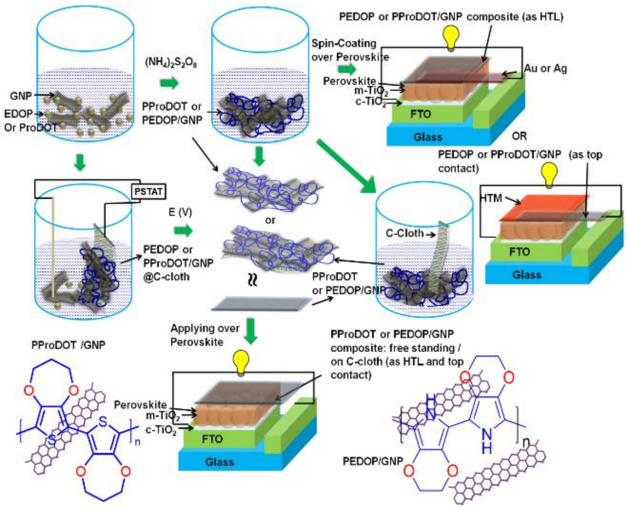


RESEARCH AREAS

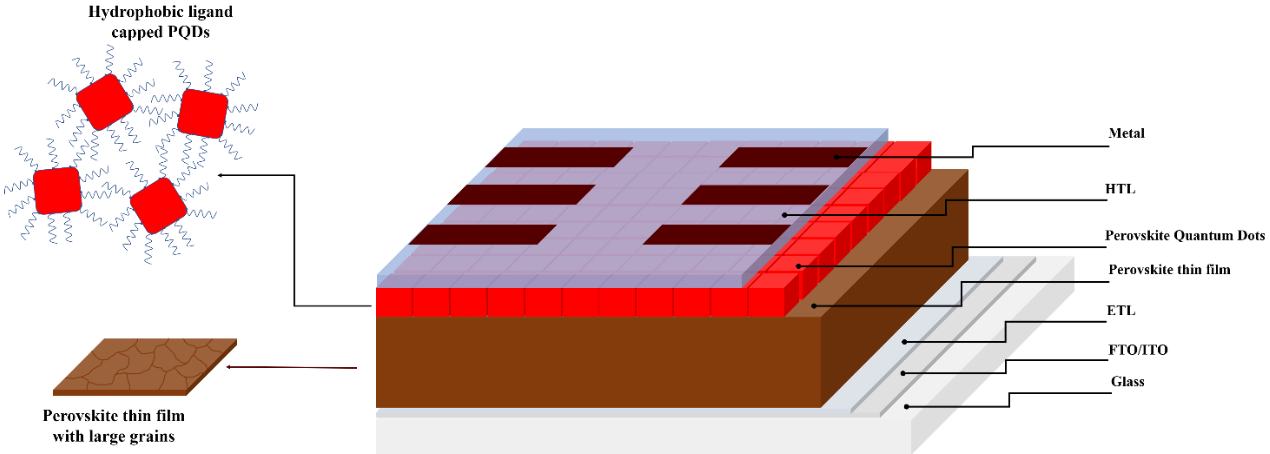
Perovskite Solar Cells

As far as the energy harvesting is concerned, the halides with perovskite architecture have emerged as the most promising photovoltaic materials which are cheap, scalable and solution processible. Even though power conversion efficiency (PCE) greater than 25% is achieved, the photo, thermal and moisture stability of these materials is far lower (less than 2 years) compared to other commercial PV technologies such as silicon PV (30 years).



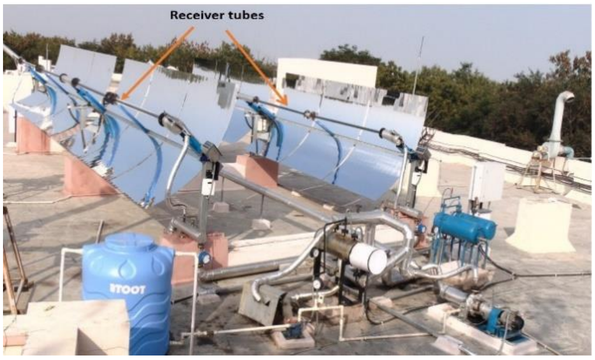


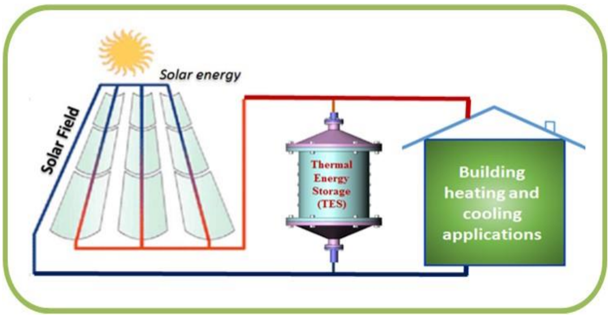
The primary objective of the DST-IIT Kanpur CRADMET center will be to design materials for energy harvesting by employing quantum and classical mechanics-enabled atomistic simulations and AI&ML algorithms. We will scan a large compositional and configurational space for predicting new materials for low-cost clean energy materials and for efficient energy harnessing. We will also employ compositional engineering of the perovskite material to improve both efficiency and the stability of the PSC. Small molecule and polymer-based additives will be incorporated to improve perovskite crystallization, passivation of defects in the bulk and/or at the surface, and can also tune the energetics and the structure of the interface for increased ambient stability. We will also work towards the development of low-cost, thermally and chemically robust transport materials, both hole and electron transport layers based on metal oxides to improve the thermal and photostability of the resulting solar cells. Automated advanced optical and electrical characterization and analysis of the perovskite solar cells will be performed to study and elucidate the materials degradation mechanism. The materials and device characterization data will be fed into AI/ML algorithm to predict environmentally robust compositions, that will be synthesized using automated and roboticized processing flow.

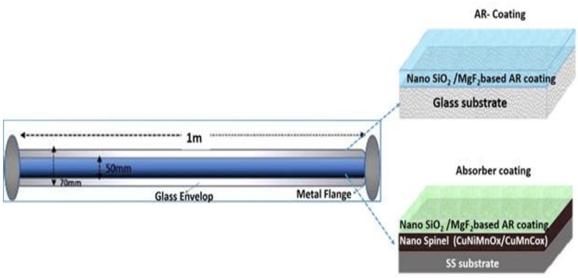


RESEARCH AREAS

Solar Thermal

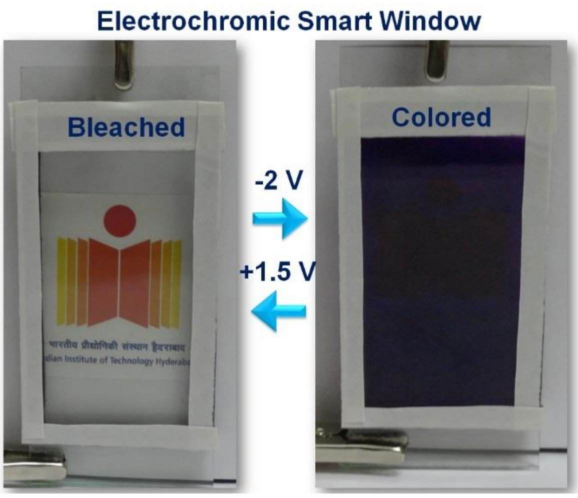






Solar receivers/collectors play an essential role in solar thermal-based hot water heating and cooling systems for buildings, steam generation for various industrial applications, and power production. Solar thermal energy is extensively used in industrial and domestic applications like solar drying operation, space heating, cooling, water heating, desalting of water, etc., by non-concentrated and concentrated solar thermal (CST) systems. The solar receiver tube is one of the critical components in solar thermal technology. The evacuated tube solar collector is the most extensively used solar thermal collector in the market. The development of novel materials with low cost and high solar absorptance is more critical for economic and high-performance solar energy harvesting and thermal energy storage systems. Transition metal-based spinel is a suitable candidate and are typically used for solar absorber material due to the presence of partially filled d-orbitals, which allows for excellent absorption of solar radiation and is tuned to get a spectral selective nature by a suitable combination of two or three transition metal oxides. At the first stage synthesis of nano spinel and low refractive materials (MgF_2/ SiO_2) will be performed for coating development from lab to prototype receiver tube (1m). Moving forward we will focus on spinel-based nanocomposite PCM from lab to 1 kWh prototype. Further, design and fabrication of solar receiver tubes and thermal storage system Integration and validation by using center's facility.

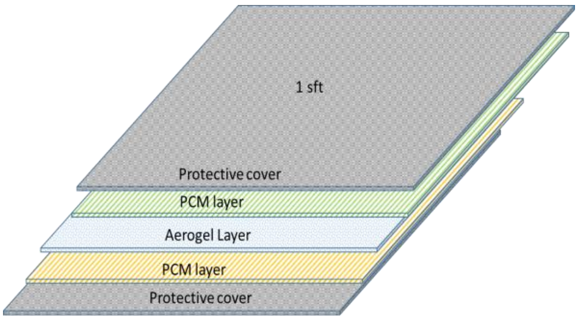
Smart Windows



The exponentially increasing demand for energy in the domestic sector may be mitigated to a large extent by efficiently modulating the indoor temperature and light. A reliable smart window technology can lead to efficient utilization of energy by modulating indoor cooling and lighting and together with import substitution, this technology will directly result in profound national, industrial and societal impact. Net-positive energy buildings are an integral part of a designed smart city and smart windows form inevitable components of such buildings. At DST-IIT Kanpur center we will be synthesizing a wide range of novel viologens confirming their applicability to smart windows by characterizing them in terms of their electro-optical properties (switching kinetics, optical modulation, reversibility, coloration efficiency) and their operational and shelf stability in the form of small area devices. The best performing electrochromic materials and electrolytes will be scaled up.

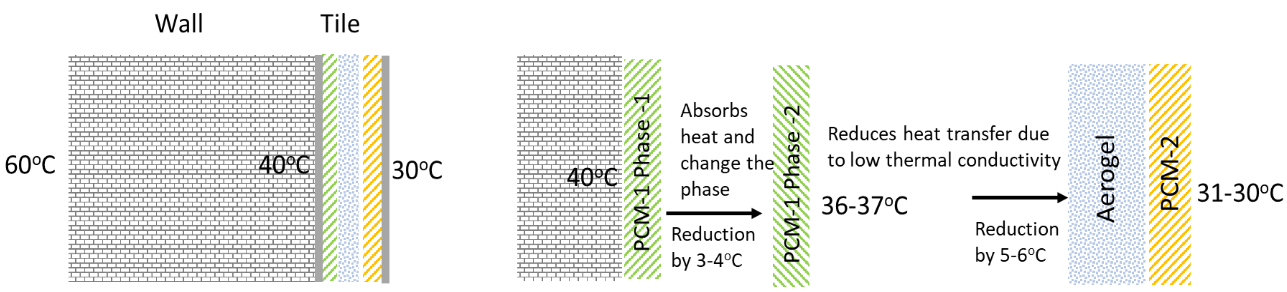
RESEARCH AREAS

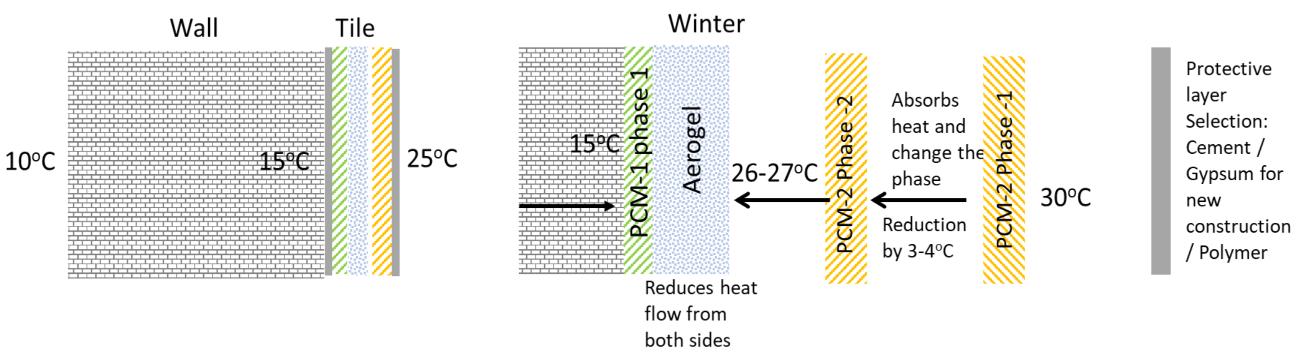
Thermo-Regulating Tiles



Thermal insulation to the buildings for reducing the indoor ambient temperature in summer and keeping the indoor space warm during winter is the most desired product, which can reduce the electricity load required for air conditioning. The products available in the market related to this domain are thermal insulation paints for walls and roofs, plaster, bricks, etc. Presently, thermal insulation is generally achieved by adding hollow glass microspheres to the matrix such as paint or putty. In order to achieve the optimum temperature inside the building, DST-IIT Kanpur center will use a high enthalpy and low-cost solid-state (SS) shape stabilised phase change material along with the existing aerogel technology for producing an effective thermo-regulating tiles. SS shape stabilised phase change materials for thermal energy storage have received increasing interest because of their high energy-storage density and inherent advantages over solid-liquid counterparts (e.g., leakage free, no need for encapsulation, less phase segregation and smaller volume variation). The novelty of this investigation is the development of thermos-regulating tiles with a PCM (SS/Shape stabilised) and Aerogel powder that will be fabricated with the help of 3-D printing technology at DST-IIT Kanpur center.

Target to achieve





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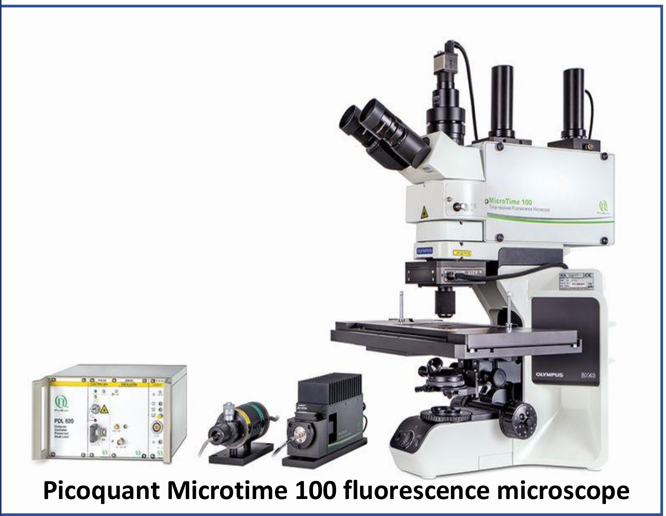
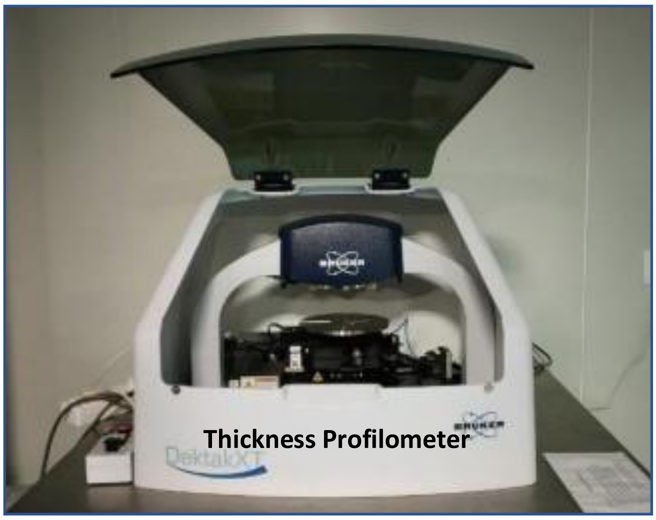

Picoquant Microtime 100 fluorescence microscope

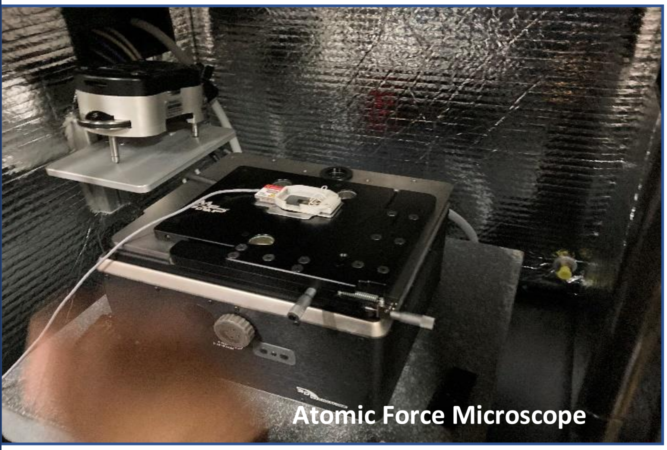

Thickness Profilometer


PANalytical XRD


X-ray Photoelectron Spectroscopy

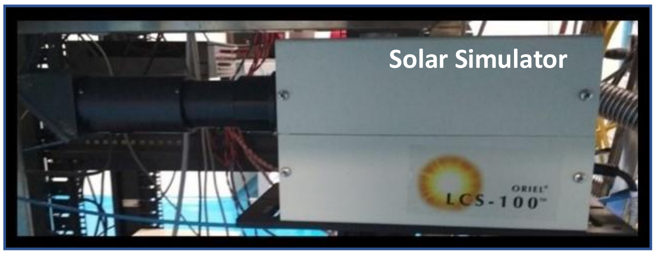

External Quantum Efficiency


Titan G2 60-300


Atomic Force Microscope


Glove-Box


FluoTime 300 Lifetime Spectrometer


Solar Simulator

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सत्यमेव जयते