



Abstract of the Thesis



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Title of Thesis: **INVESTIGATION AND ANALYSIS OF
FLUID BASED ABSORPTION FILTERS FOR SOLAR
PVT SYSTEM**

ABSTRACT

The fast depletion of fossil fuels and the growing demand for energy around the world have made it necessary to switch to more sustainable sources, with solar energy emerging as a premier, clean, and inexhaustible alternative. While silicon (Si) solar cells currently dominate 95% of the global market, they face significant operational hurdles in outdoor environments. Specifically, module temperatures often exceed 60°C, triggering thermal degradation that severely reduces electrical efficiency.

To address this, Photovoltaic-Thermal (PVT) systems were developed to extract heat directly from panels using transfer fluids. However, conventional PVT designs suffer from a fundamental trade-off: they cannot maximize electrical and thermal efficiencies simultaneously, as thermal output must be kept low to prevent the PV module from overheating.

Spectral Beam Splitting (SBS) technology offers a solution to this conflict. By separating the solar spectrum into specific wavelength ranges, the system can direct the responsive range of silicon cells (751 nm to 1126 nm) toward the PV receiver while diverting the remaining thermal radiation to a secondary absorber. Liquid-based SBS systems are particularly effective as they offer tenable optical properties and cost-efficiency.

Despite extensive numerical and laboratory-based research, there remains a critical gap in experimental validation under natural solar conditions. This study addresses this gap by developing a compact, portable experimental platform designed for year-round outdoor testing. The research focuses on the fabrication and analysis of a fluid-based absorption filter integrated with a PVT system, capable of testing various fluids to optimize radiation filtering.

Following a comprehensive review of organic and nanofluid-based SBS filters, this work identifies water-based Titanium Dioxide nanofluid as a high-potential



candidate for commercial implementation. Spectroscopic analysis of 12 samples (TiO_2 and ZnO at concentrations of 0.01% to 0.05%) determined that a 0.04% concentration of TiO_2 is the most effective for BSPVT systems, as it balances high transmissivity with effective UV and infrared attenuation.

The experimental setup features a modular, adjustable support structure for precise tilt orientation, a 10W crystalline silicon PV module, and high-precision instrumentation including pyranometers and thermocouples. By systematically comparing three configurations i.e. standalone PV (Case 1), PV with an empty filter (Case 2), and PV with circulating nanofluid (Case 3) the study isolates the thermal and optical impacts of the filter.

Testing at variable volumetric flow rates (52, 58, and 70 LPH) revealed that 58 LPH provides the optimal balance, maintaining a stable 7.4% electrical efficiency and 66% thermal efficiency, totalling 73% overall efficiency. Ultimately, this research validates the TiO_2 -based spectral beam-splitting approach as a superior method for total energy harvesting, transforming waste heat into a valuable secondary energy stream and providing a more comprehensive solution than traditional solar systems.

This PhD Thesis will be useful for academicians, solar energy & photovoltaic (PV) researchers, thermal & fluid engineers, nanofluid & materials scientists, solar PV-Thermal system manufacturers & R&D Teams as it provides experimental data and theoretical validation on beam-splitting photovoltaic-thermal (BSPVT) systems

List of Publication(s)

1. Jiwanapurkar, P.R., Bhargav, H.A. and Ramani, B. (2023) 'Fluid based solar spectral beam splitters for hybrid photovoltaic thermal systems: a review', Int. J. Renewable Energy Technology, Vol. 14, No. 3, pp.241–258.
2. P. Jiwanapurkar and H. Bhargav, "Spectroscopic Analysis of Water-Based TiO_2 and ZnO Nanofluid for Fluid-Based Beam Split Photovoltaic-thermal System," Journal of Solar Energy Research, vol. 10, pp. 45–55, Mar. 2025, doi: 10.22059/jser.2025.379717.1445.
3. P. Jiwanapurkar, H. Bhargav, C. Sonawane, C. K. Chan, D. Varsheny, and S. Dixit, "Experimental investigation of a TiO_2 nanofluid spectral beam-splitting photovoltaic-thermal system under outdoor conditions," Discover Nano, vol. 21, no. 1, p. 94, 2026, doi: 10.1186/s11671-026-04507-8.