

SciCom

Turning Up the Heat on Cancer: A Novel Automated Approach to **Photothermal-Therapy Characterization for Cancer Therapy**

Abstract

To enable precise and reproducible photothermal experiments, we developed a fully automated 3D printer-based platform integrated with a custom-built bifurcated excitation/emission spectrofluorometer attachment. The system was tested using top-down synthesized reduced graphene quantum dots (RGQDs), which exhibit strong near-infrared (NIR) fluorescence and photothermal properties. An 808 nm laser is collimated into one end of a bifurcated fiber for excitation, while emission is collected from the same axis and filtered through a high optical density 850 nm longpass filter to minimize backscattering. A T-type thermocouple, housed in a custom-machined aluminum guide, enables highly stable and accurate temperature measurements across 96-well plates. The automated platform allows for synchronized laser excitation, fluorescence acquisition, and thermal mapping in real time. Using RGQDs as the model nanomaterial, we validated the system's ability to monitor photothermal effects and NIR spectral changes with high reproducibility. This cost-effective setup offers a scalable solution for high-throughput nanomaterial characterization and photothermal research.

Introduction

<u>Why Photothermal Therapy (PTT)?</u>

- Minimally invasive treatment: Photothermal therapy (PTT) enables localized tumor ablation using heat, reducing damage to surrounding healthy tissues.
- Synergistic potential: PTT can enhance the effectiveness of chemotherapy or immunotherapy by improving drug uptake and inducing immune responses.

Fallbacks of current PTT Experimental Approaches

- Lack of automation and control: Previous PTT studies often rely on manual laser application and limited well-by-well analysis, reducing consistency and reproducibility across large datasets.
- Limited real-time monitoring: Conventional setups lack integrated systems for simultaneous thermal and spectral tracking—this device enables high-throughput, automated temperature and fluorescence measurements, allowing for precise and scalable PTT experimentation.

Our Automated Setup and Use of GQDs in PTT

- Efficient NIR absorption and heat conversion: GQDs exhibit strong absorption in the near-infrared region and efficiently convert light to heat, making them highly effective photothermal agents for controlled cancer cell ablation.
- Enables future PTT-triggered chemo release studies: This automated setup can be used to systematically evaluate photothermal-triggered release of chemotherapeutics from nanocarriers like GQDs, offering precise control over dosing and timing for advanced cancer treatment strategies.

<u>Ugur C. Topkiran^{1*}, Ibrahim E. Bozkurt², Anton V. Naumov¹</u>

¹Department of Physics and Astronomy, Texas Christian University; ²Department of Computer Science, Texas Christian University

Automated 3D-Printer Based PTT Charaterization Setup







Figure 1. a) Schematic of the custom 3D-printed component used to secure the fiber optic cable onto the 3D printer platform. b) Photograph of the aluminum thermocouple guide manufactured to stabilize the thermal probe within the printer's filament housing. c) Representation showing the fixed 9.82 mm separation between the thermocouple tip and the end of the aluminum guide to prevent heat sinking during measurements



Figure 2. a–e) NIR fluorescence spectra collected using the automated setup. a) DI water 20 control well. b) **RGQD-treated well without laser exposure. c–e) RGQD-treated wells subjected to 808 nm laser irradiation** for c) 1 minute, d) 5 minutes, and e) 10 minutes. f) Temperature distribution map corresponding to Run 2, from which the plotted spectra were collected.

Figure 3. Schematic of the bifurcated excitation/emission spectrofluorometer attachment

Figure 4.) Temperature distribution map of the positive control well (DI water). b) Temperature distribution map of the RGQD-treated well after laser irradiation. c) **Averaged temperature change plot for each treatment condition d) Experimental** layout representation for the RGQDtreated well.

- Bifurcated attachment offers compact, cost-effective NIR fluorescence monitoring for real-time analysis. Automated 96-well platform enables reproducible,
- high-throughput PTT studies with synchronized excitation and measurement.

NIH National Institutes of Health

Bifurcated Spectrometer Attachment

Conclusion

We created an affordable, fully automated lab device that can study how tiny materials heat up when exposed to laser light. This system is built from a modified 3D printer and uses a custom optical sensor to shine light and collect signals from special materials. We tested the setup using a kind of carbon-based nanomaterial called graphene quantum dots, which glow under near-infrared light and can heat up when excited. Our device tracks both temperature and glowing light signals at the same time in small samples, making experiments faster, more precise, and easier to repeat. This tool will help scientists better understand these materials and explore their use in medical treatments like laser-based cancer therapy.

