Temperature Dependence of Optical Properties of Nitrogen Doped Quantum Dots, Graphene Oxide, and Single-walled Carbon Nanotubes

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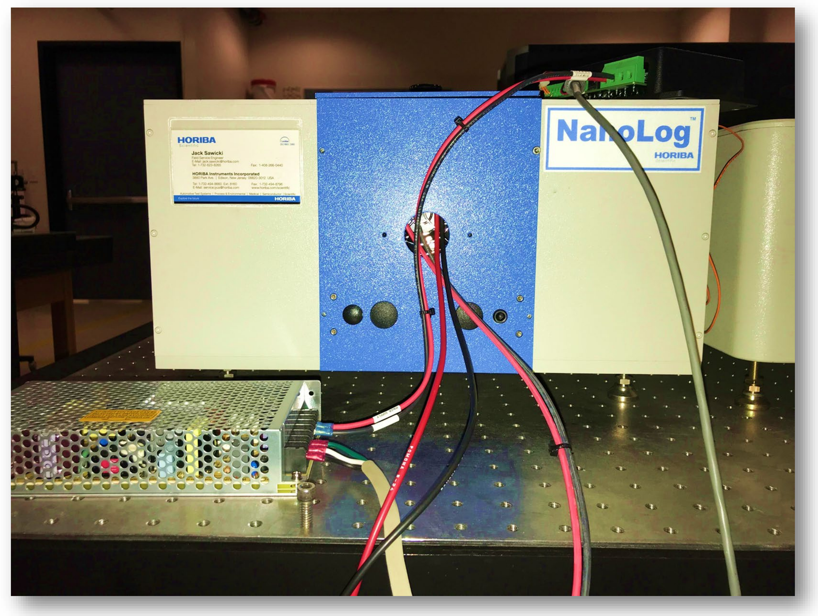
Abstract

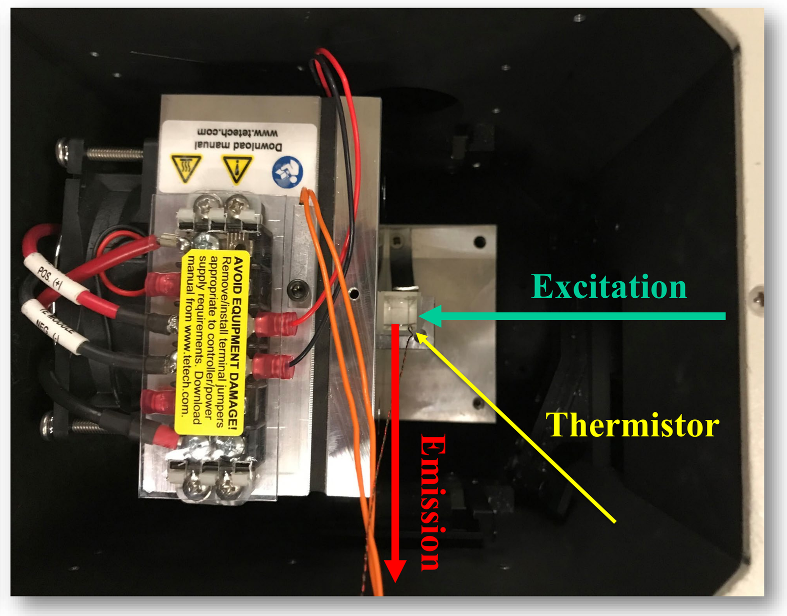
Fluorescing nanoparticles are utilized widely for applications in optoelectronics, sensing, biomedical imaging, and cancer detection. In these applications it is often overlooked that the temperature may affect the optical performance of nanomaterials in optoelectronic devices or even in the biological live systems. In this work we built an apparatus for controllable temperature adjustment of aqueous dispersions of nanomaterials inside the spectrometer as their fluorescence spectra are being monitored. This module is built based on the thermoelectric elements with a corresponding controller and affixed to a cuvette holder of the fluorescence spectrometer. Using this setup, we assess the fluorescence of 0D, 1D and 2D carbon nanomaterials: graphene quantum dots, carbon nanotubes, and graphene oxide subjected to temperatures ranging from room temperature to 100 ºC. These experiments will allow us to assess the performance of nanomaterials as they fluorophores at a variety of temperatures and will serve as basis for understanding the thermal effect on their optoelectronic and, potentially, structural properties.

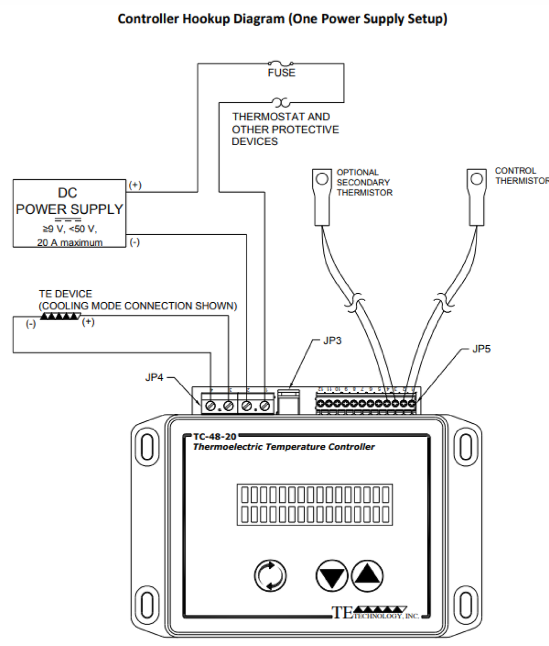
Purpose

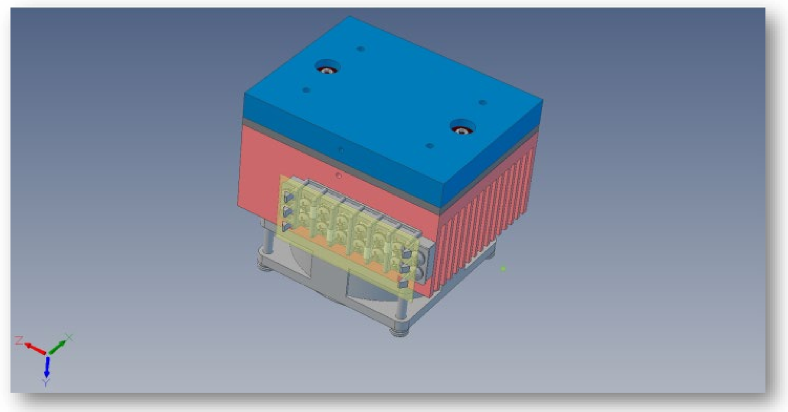
The purpose of this experiment is to explore the optical properties of N-GQDs, GO, and Carbon Nanotubes as they are subjected to temperatures from 25C to 100C, and to see if any properties are permanent after heat application.

Thermoelectric Module









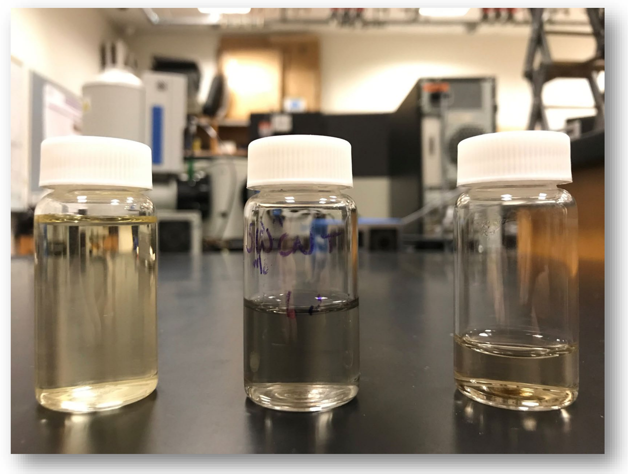
- A thermal electrical module was purchased from TE Electric.
- A temperature controller was purchased from TE Electric to ensure controllable temperature adjustment.
- A pipette holder was made, from scratch, out of aluminum, and optimized for quick heating and cooling.
- Once the system was constructed within the iHR320 spectrometer, placement of the module was optimized for heat transfer to the cuvette.
- Thermistors were connected to the module and aqueous solution the controller to ensure proper communications between the systems (with a 0.1-0.2C error).

Materials

N-GQDs:
- Synthesized from glucosamine in a microwave.
- Dispersed in water via ultrasonic tip agitation.
- Green emission with 400nm excitation.

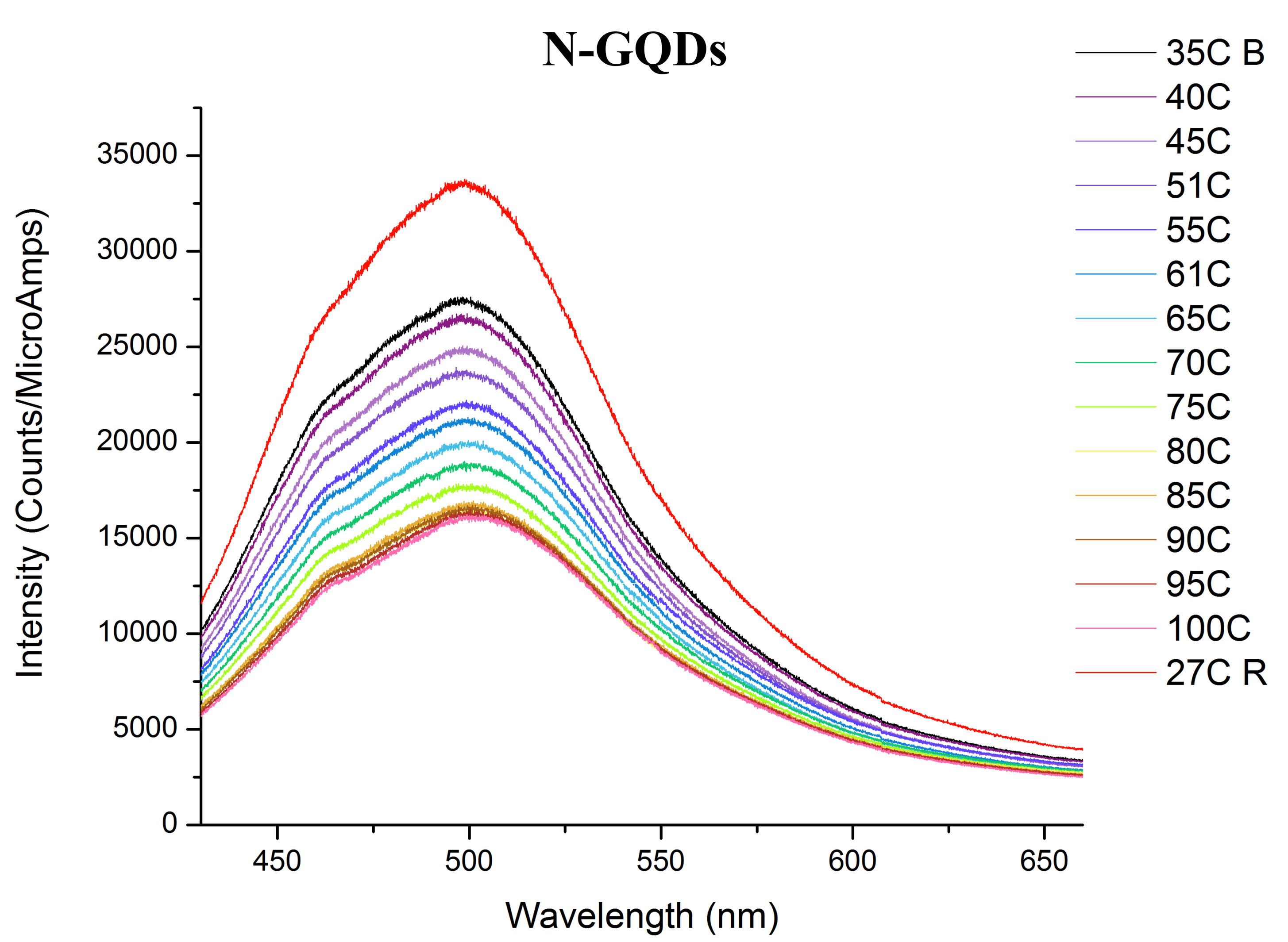
Carbon Nanotubes:
- Purchased commercially
- Dispersed in aqueous sodium deoxycholate surfactant via ultrasonic tip agitation
- Near-infrared emission with 640nm excitation.

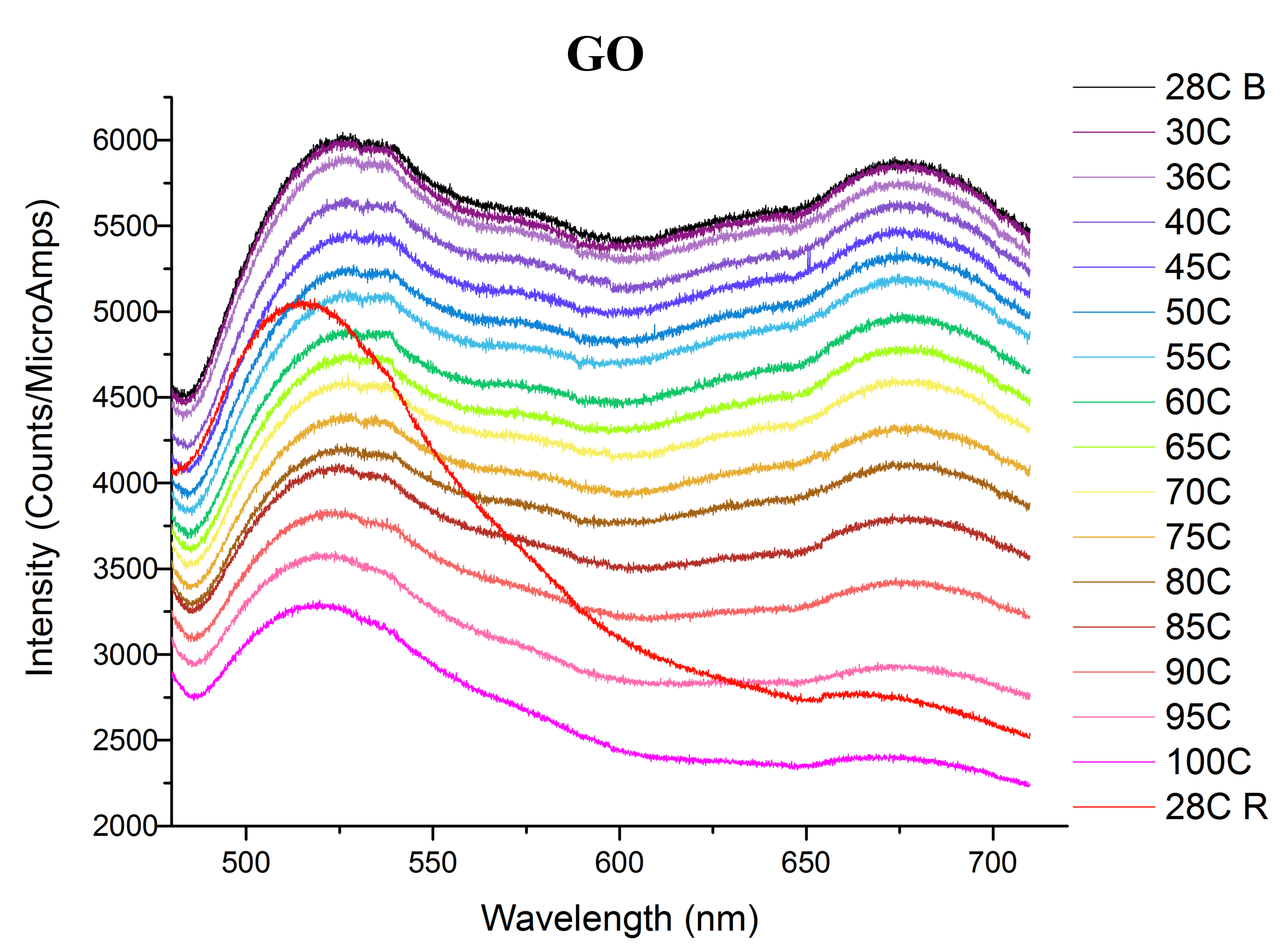
GO:
- Purchased commercially
- Dispersed in water via ultrasonic tip agitation.
- 14.7nm slit and 4 covers

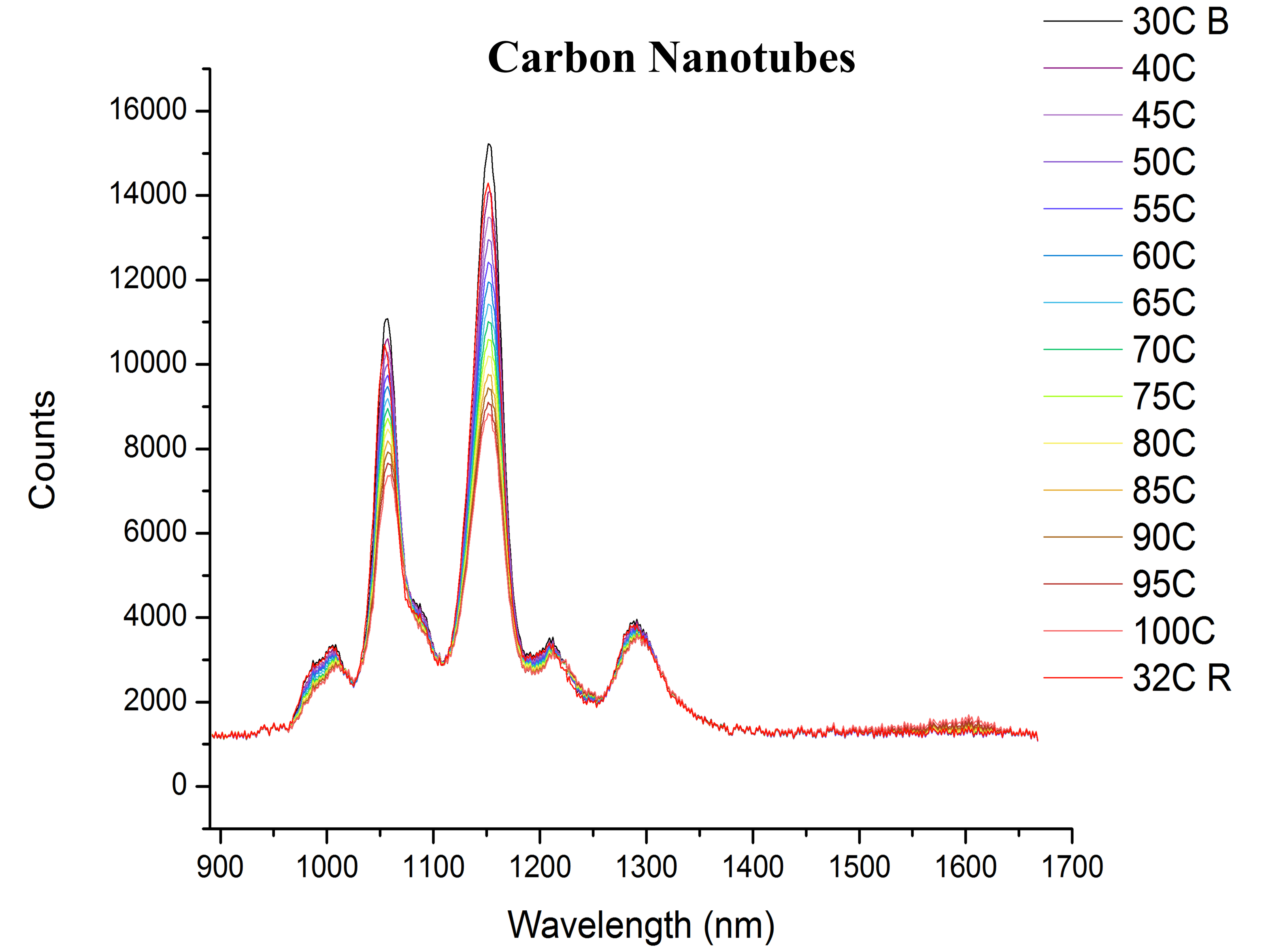


[N-GQDs] 10.1 mg/mL [Carbon Nanotubes] 4.6 mg/mL [GO] 0.031 mg/mL

Results: Fluorescence with Temperature







Findings

N-GQDs
- Fluorescence quenching of the whole spectrum with temperature
- The process is irreversible: after cool down the emission remained quenched.
- Can be attributed to thermal reduction of oxygen functional groups.

GO
- Fluorescence quenching with temperature: red feature is quenched more at higher temperatures.
- The process is partly irreversible: after cool down green emission is partly restored, but red remains quenched.
- Can be attributed to thermal reduction of some oxygen functional groups. Greater quenching of red features may arise from primary destabilization of large graphitic islands on GO surface.

Carbon Nanotubes
- Fluorescence quenching of the whole spectrum with temperature
- The process is reversible: after cool down the emission almost fully restores.
- No oxygen functional groups present on carbon nanotubes - reduction does not occur. Surfactant coating may dissociate with temperature => quenching.

Summary

- Thermoelectric system capable of heating/cooling inside the spectrometer was constructed.
- N-GQDs, GO, and Carbon nanotubes show evidence of thermal quenching.
- For N-GQDs and GO the quenching is partly or fully irreversible. Nanotube emission is restored after cool down.
- Irreversible changes are attributed to reduction of some of the oxygen-containing functional groups on graphitic surface
- Future research will involve assessment of optical properties of these nanomaterials upon cooling and the development of the theoretical framework to explain the effects observed.