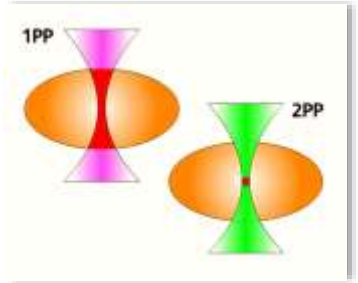
Microfabrication of fine-feature structures by two-photon polymerization polymerization of a (meth)acrylate-based based resin

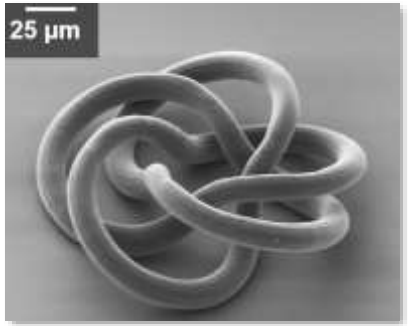
Presenter: Maksim Sargsyan

Ultrafast Beams and Applications
17-23 June 2024, CANDLE, Armenia

Multiphoton Polymerization

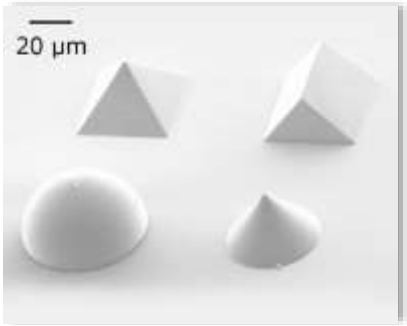


Difference of conventional one-photon polymerization and two-photon polymerization



Knot Structure: Demonstrating 3D Potential

www.isc.fraunhofer.de



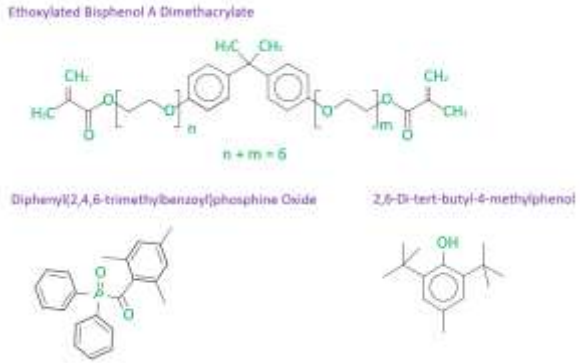
Demonstration of Microoptical Elements using 2PP

Advantages:

- **High Precision:**
  Fabrication of intricate micro- and nanoscale structures is possible.
  Excellent spatial resolution due to nonlinear absorption.
- **3D Fabrication:**
  Capable of producing complex 3D structures in a single step.
- **Material Versatility:**
  Can be used with a wide range of materials (**acrylates, hydrogels, organic/inorganic hybrids, epoxides**)

Materials and Methods

MOIIN Tech Clear – (meth)acrylate based resin



Chemical structure of the used resin.

https://www.moiin-resins.com/

High Optical Transparency – Suitable for parts requiring transparency or visibility of interior features.

Durability – Provides strong mechanical properties, ensuring long-lasting performance (tensile strength at break: 63 MPa, flexural modulus: 2500 MPa, shore D Hardness: 82)

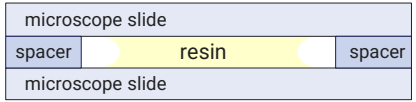
Biocompatibility:

- Safe for use in medical and dental applications.
- Suitable for 3D printing and rapid prototyping of new generations of microfluidic channels for biomedical applications.

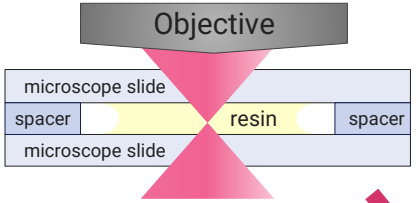
Materials and Methods

Design of the Target Structure (DXF, STL)

Sample Preparation

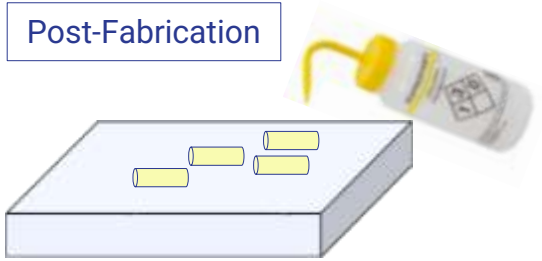


Direct Laser Writing



Stages

Post-Fabrication

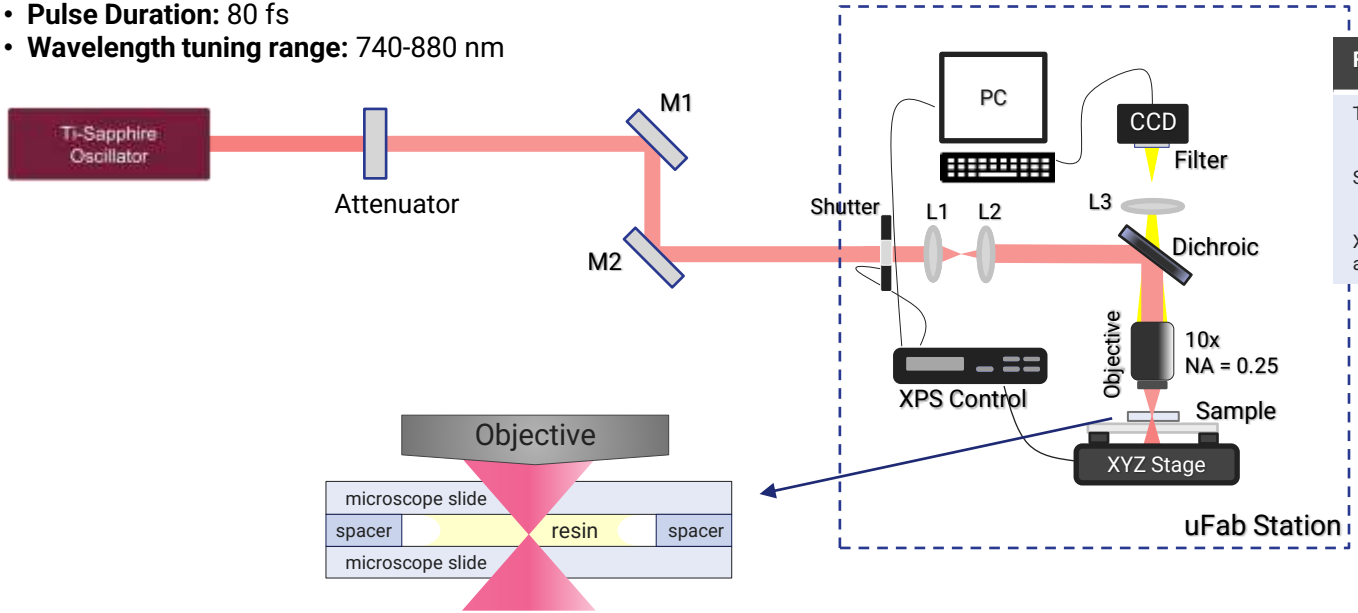


Rinsing the sample with isopropanol for 3 minutes, cleaning with compressed air for 2-3 minutes, and a final 3-minute ultrasonic bath with isopropanol to remove any remaining solvent residues.

Characterization

Experimental Setup

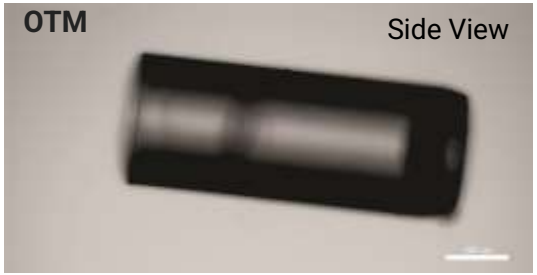
- **Repetition Rate:** 81 MHz
- **Pulse Duration:** 80 fs
- **Wavelength tuning range:** 740-880 nm

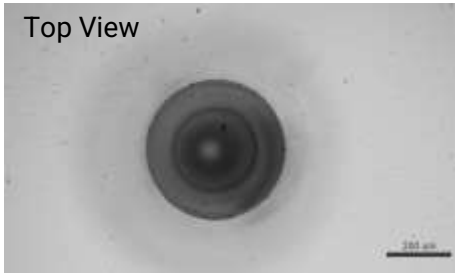


Features of uFab workstation	
Travel Range	100 x 100 mm (XY), 25 mm (Z)
Scanning Speed	up to 300 mm/s (XY), up to 5 mm/s (Z)
XYZ positioning accuracy	±50 nm

Fabrication Results

Tube with patterned inner surface

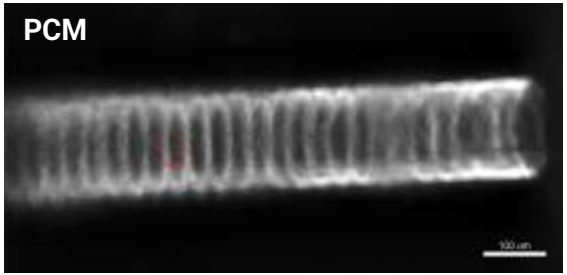


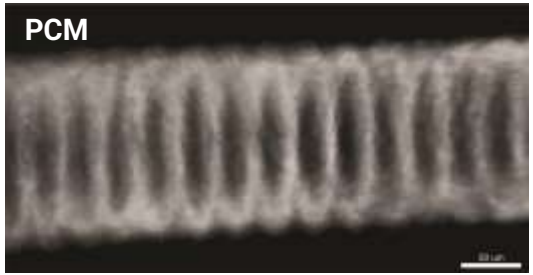


Fabrication parameters:
Wavelength: 800 nm
Pulse Duration: 80 fs
v = 300 um/s
P = 131.25 mW

External Diameter: 415 um
Length of the tube: 1 mm
Fabrication Duration: about 40 min

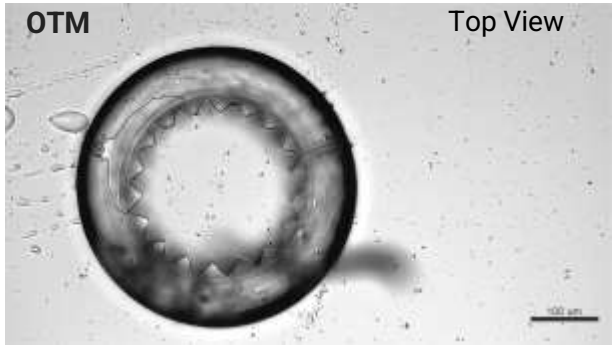
Patterned Helical Structure: period of the helix is 30 μm

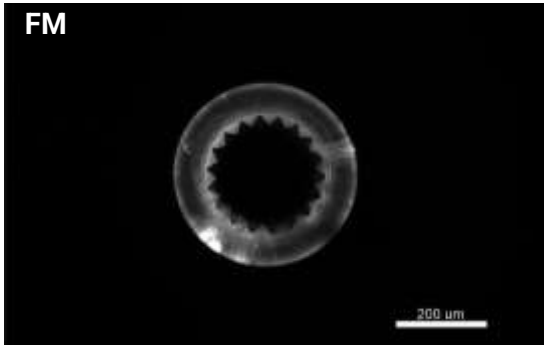




Fabrication Results

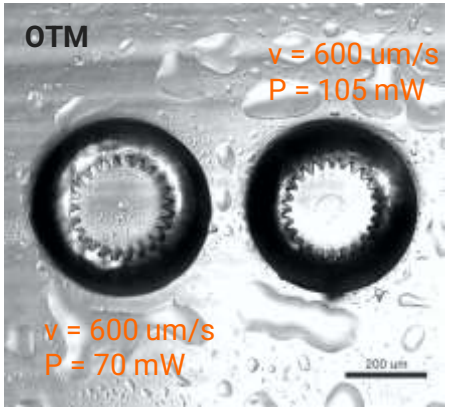
Internal Gears with Various Features





Fabrication parameters:
Wavelength: 800 nm
Pulse Duration: 80 fs
v = 800 um/s
P = 52 mW

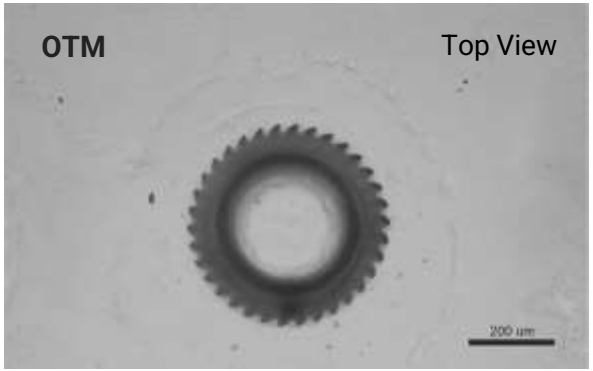
External Diameter: 400 um
Height: 150 um

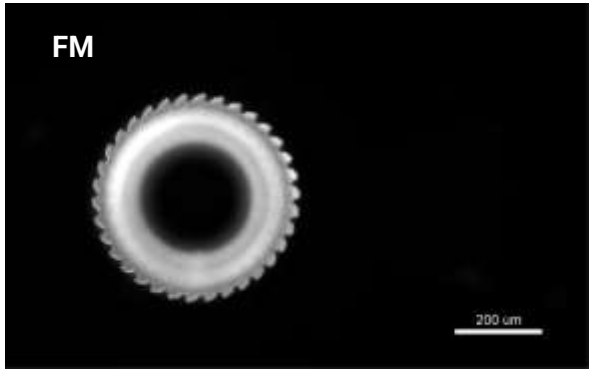


External Diameter: 400 um
Height: 180 um

Fabrication Results

Saw-like structures





Fabrication parameters:
Wavelength: 800 nm
Pulse Duration: 80 fs
v = 600 um/s
P = 105 mW

Outside Diameter: 450 um
Height: 300 um

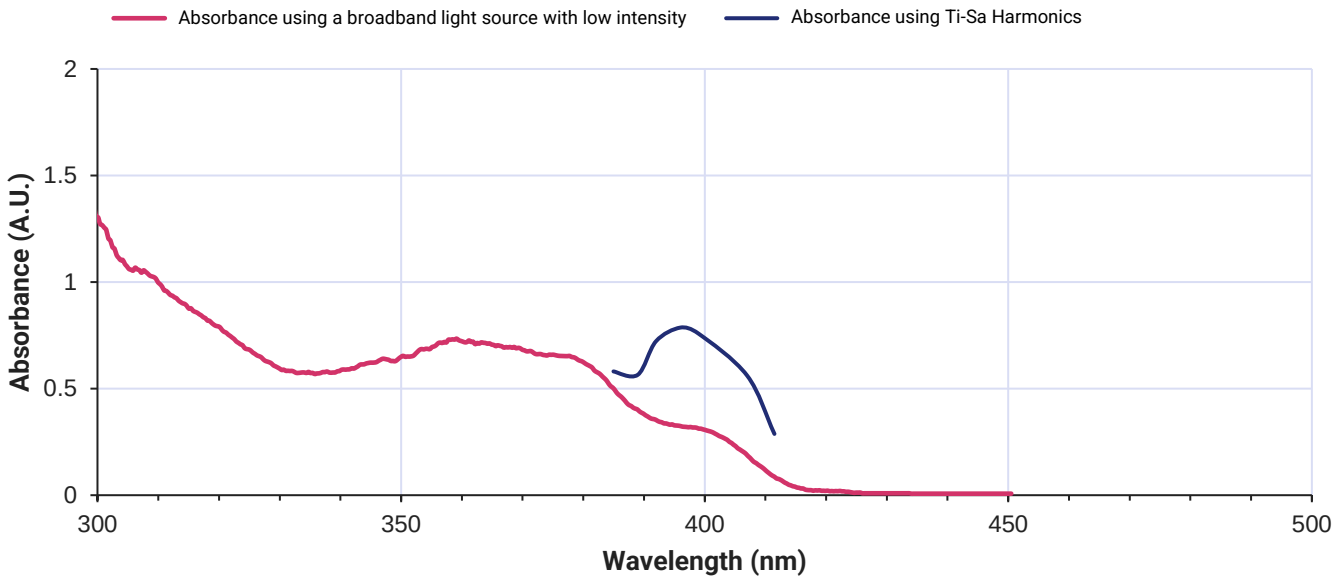
Usual fabrication defects observed: cracks, waviness, bent corners, etc.

Further fabrication optimization is needed!

resolution limitations due to the nature of chain reaction polymerization

Optical Properties of the Material: Absorption and Fluorescence Studies

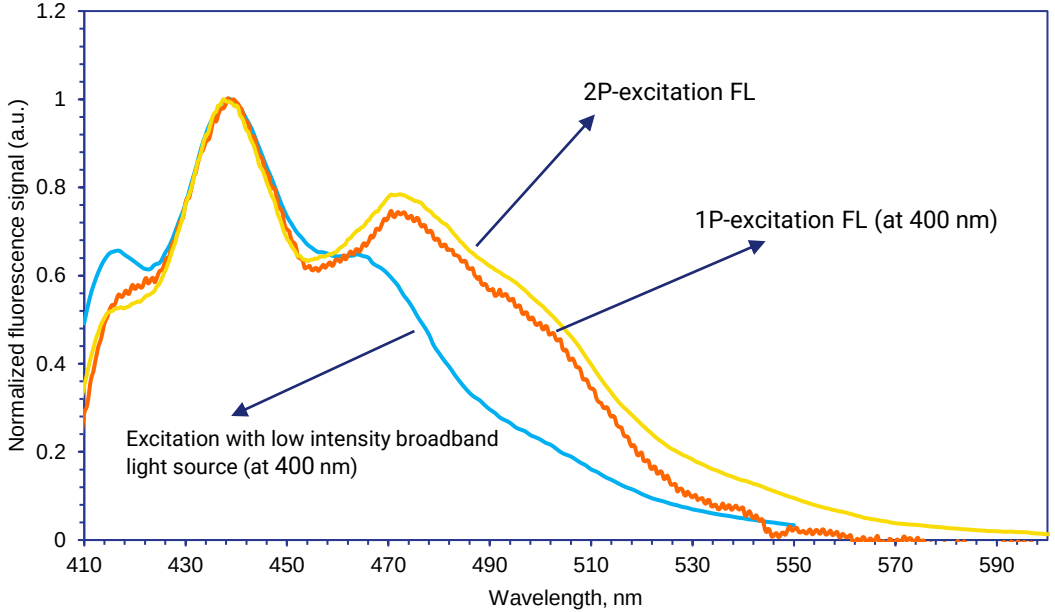
Absorbance curves



measurements using higher-power laser harmonics are accompanied by polymerization

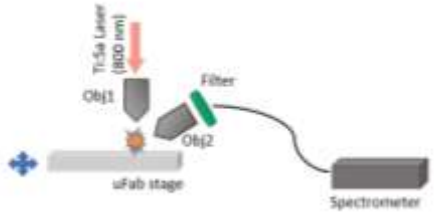
Optical Properties of the Material: Absorption and Fluorescence Studies

Fluorescence Spectra

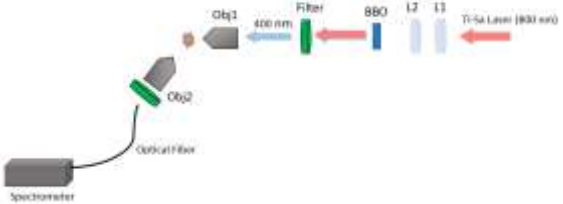


measurements using higher-power lasers are accompanied by polymerization

2P-excitation FL Measurement Setup



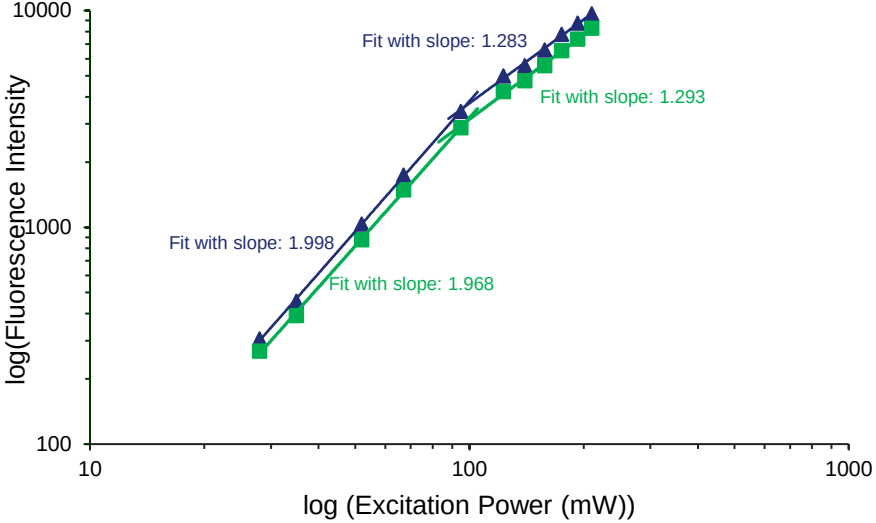
1P excitation FL Measurement Setup using a laser source



The differences may be due to photo-degradation, photo-dissociation, quenching, self-absorption, or another type of “invasive” light-induced reaction.

Optical Properties of the Material: Absorption and Fluorescence Studies

Dependence of 2P-excitation Fluorescence on the Laser Power

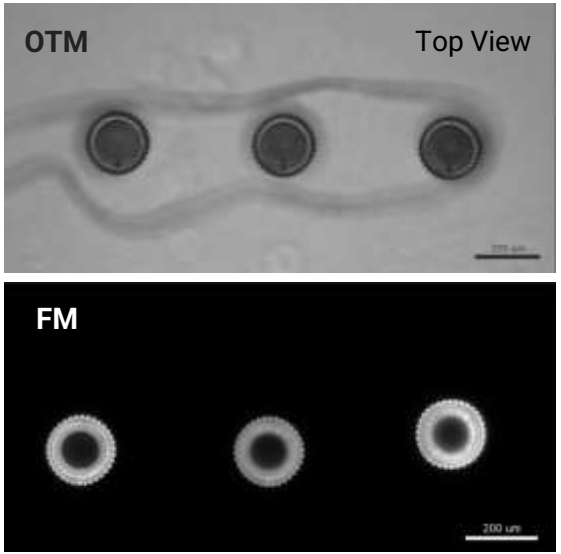


Fabrication optimization also depends on the relative concentration of the photoinitiator and polymerization inhibitor.

Chemical structure and mechanisms of polymerization should also be considered when finding optimal fabrication regimes for higher resolution 2PP.

Summary

- The viability of the 2PP method for the promising MOIIN Tech Clear resin was demonstrated by fabricating sample structures with micro-scale features (such as tubes with patterned inner surface, gears, etc.)
- The obtained results can be used for the fabrication of biocompatible structures and microfluidic devices
- Some optical properties of the material were characterized, with the results of both 1P and 2P absorption and fluorescence spectral measurements reported
- Fabrication resolution and throughput can be increased by carefully selecting the fabrication regimes (laser wavelength, intensity, and speed) based on the details of the material's chemical structure



Thank you!

Microfabrication of fine-feature structures by two-photon polymerization of a (meth)acrylate-based resin

M.L. Sargsyan[1,2], M.M. Sukiasyan[1,2], T.K. Sargsyan[1], S. Tatikyan[1], A.S. Yeremyan[1], and K. Floettmann[3]

[1] CANDLE Synchrotron Research Institute, 31 Acharyan St. 0022, Yerevan, Armenia
[2] Yerevan State University, 1 Alek Manukyan St. 0025, Yerevan, Armenia
[3] Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

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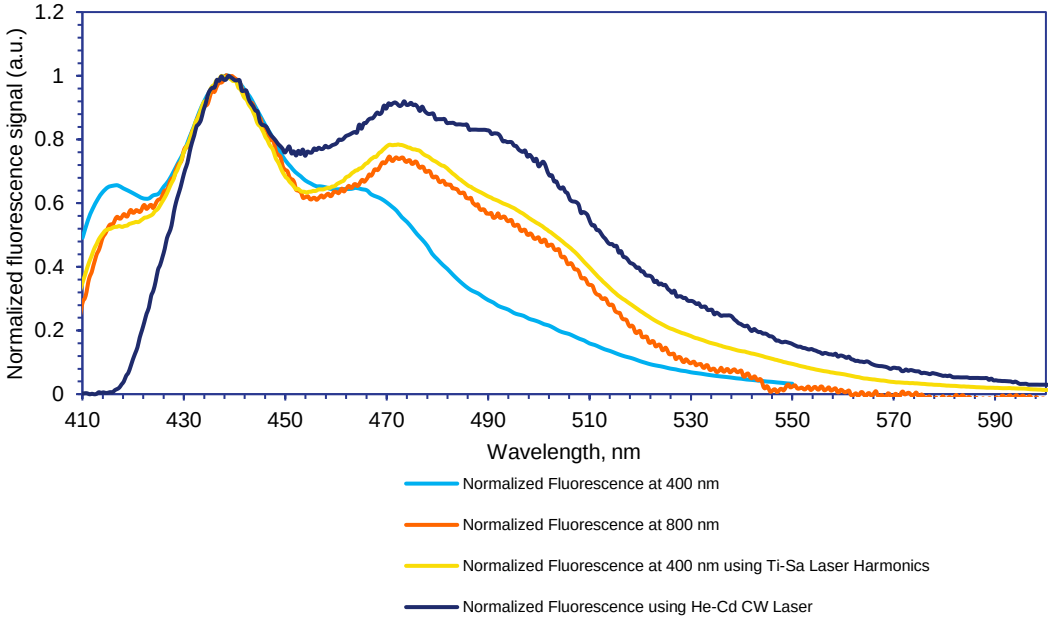
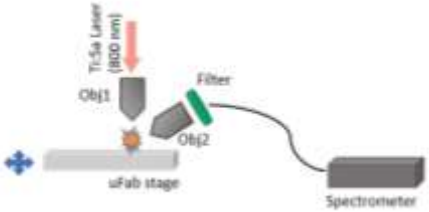
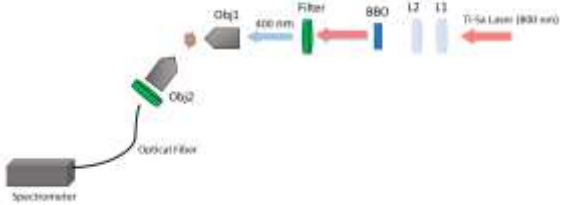
Optical Properties of the Material: Absorption and Fluorescence Studies



2P-excitation FL Measurement Setup



1P excitation FL Measurement Setup using a laser source



Experiments with a low intensity broadband light source were conducted using a Cary Eclipse fluorescence spectrometer