

Spectral Narrowing of Amplified Spontaneous Emission in One-Dimensional Photonic Crystal Super-Tamm Structure

Sudha Maria Lis S, Somnath Pandit, Someprosad Patra, Debamalya Banerjee,
and Shivakiran Bhaktha B N

Department of Physics, Indian Institute of Technology Kharagpur, West Bengal-721302, India

Abstract

In this work, studies on the optical Tamm mode of a super-Tamm structure consisting of a silver (Ag) thin film deposited on dye-doped polyvinyl alcohol (PVA) thin film coated on a SiO₂/TiO₂ one-dimensional photonic crystal (1DPhC) structure are presented.

- The spectral narrowing of the Tamm state aided amplified spontaneous emission from the structure is attributed to the strong confinement of Tamm mode in the DCM dye doped PVA layer sandwiched between 1DPhC and Ag thin film.

Fabrication of One-Dimensional Photonic Crystal Super-Tamm structure

TiO₂ sol preparation

9.3 mL Isopropanol and 3.2 mL TIP was stirred at 70 °C for 30 minutes

Added 10.3 mL of acetic acid and stirred at 70 °C for 1 hour

Added 24 mL of methanol and stirred at 70 °C for 30 minutes

SiO₂ sol preparation

TEOS + EtOH + HCl + DI-H₂O (1:0.01:25:2)

Stirred at 65 °C for 1 hour

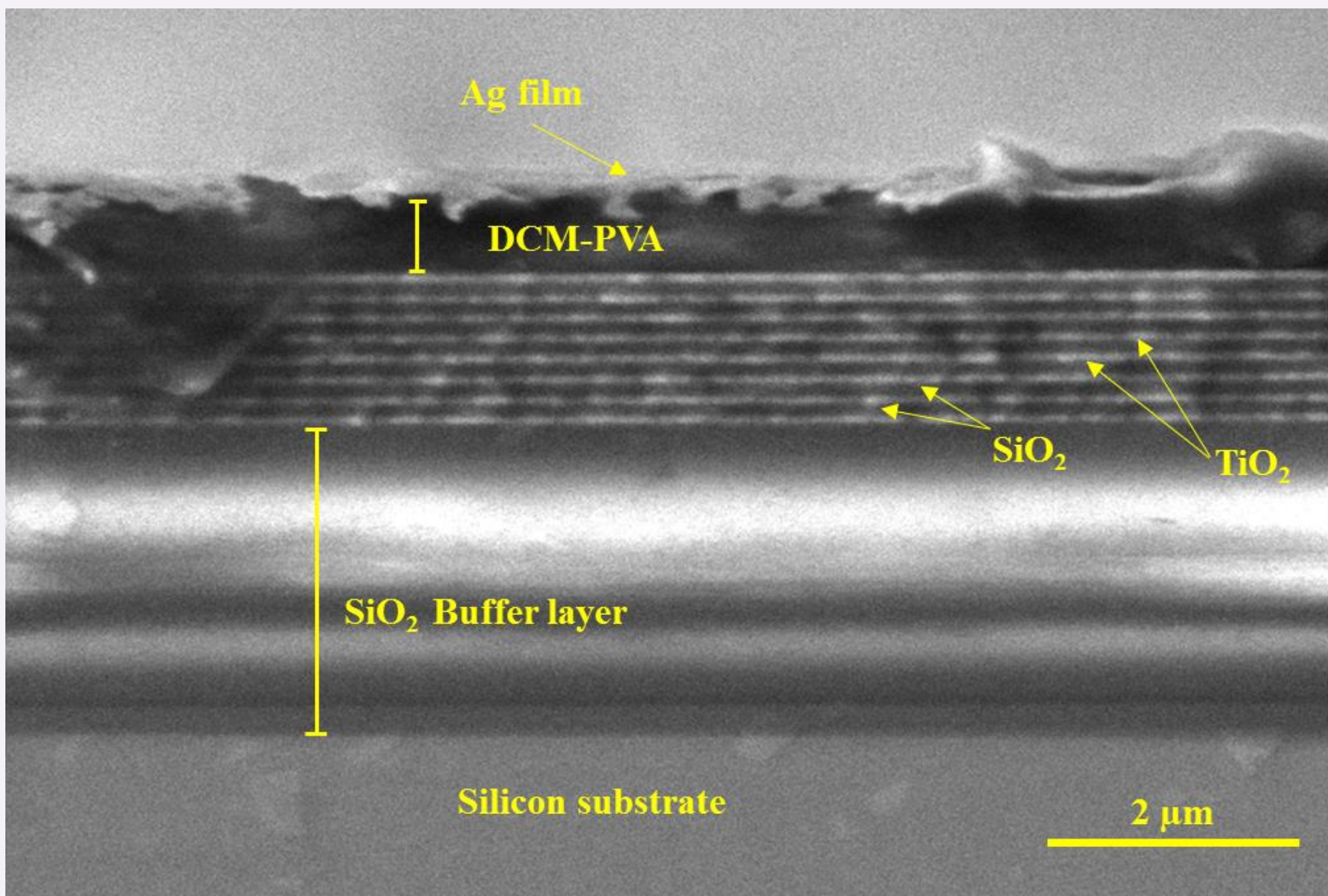
Both the solutions were then filtered and kept for aging for more than 16 hours at room temperature

Step 1: The 1DPhC consists of alternating 8 bi-layers of SiO₂ and TiO₂ thin films on SiO₂ coated silicon substrate, was fabricated by sol-gel synthesis route followed by dip coating technique.

Step 2: 0.08% DCM-PVA solution was spin coated onto 1DPhC at 3000 RPM for 30 seconds.

Step 3: The Ag film was deposited on to the DCM-PVA coated 1DPhC by using the thermal evaporation technique under 5×10⁻⁶ mbar vacuum pressure.

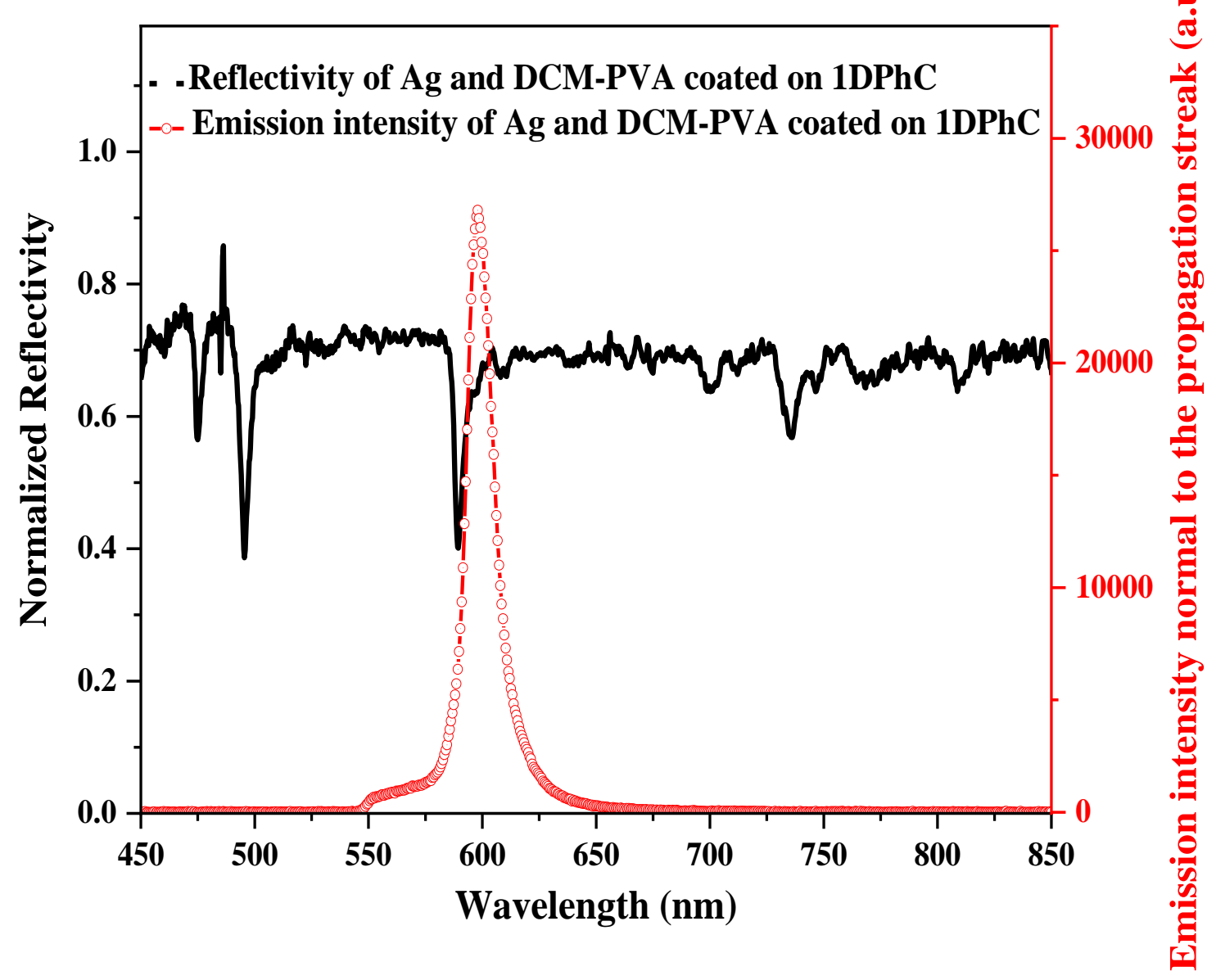
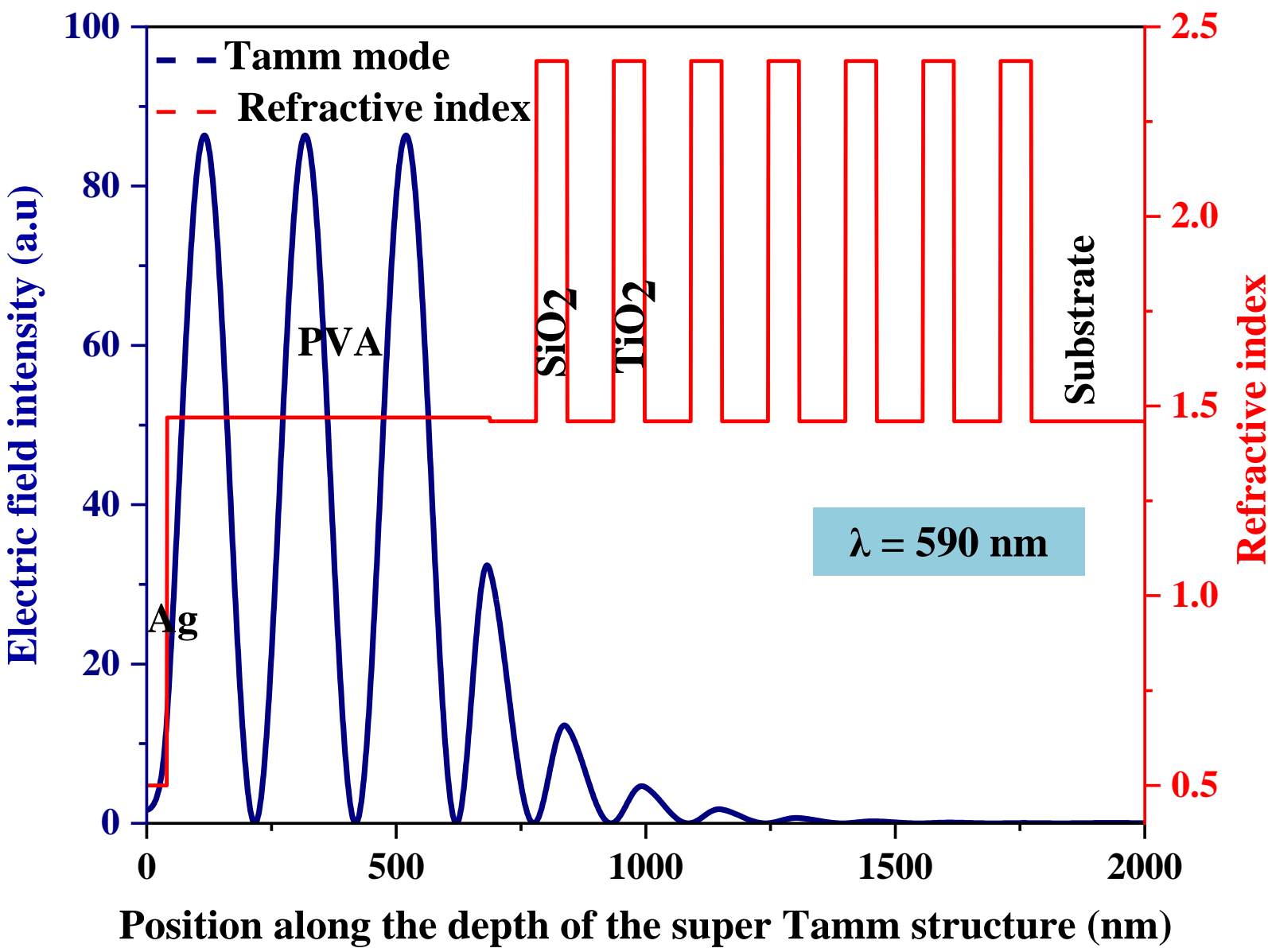
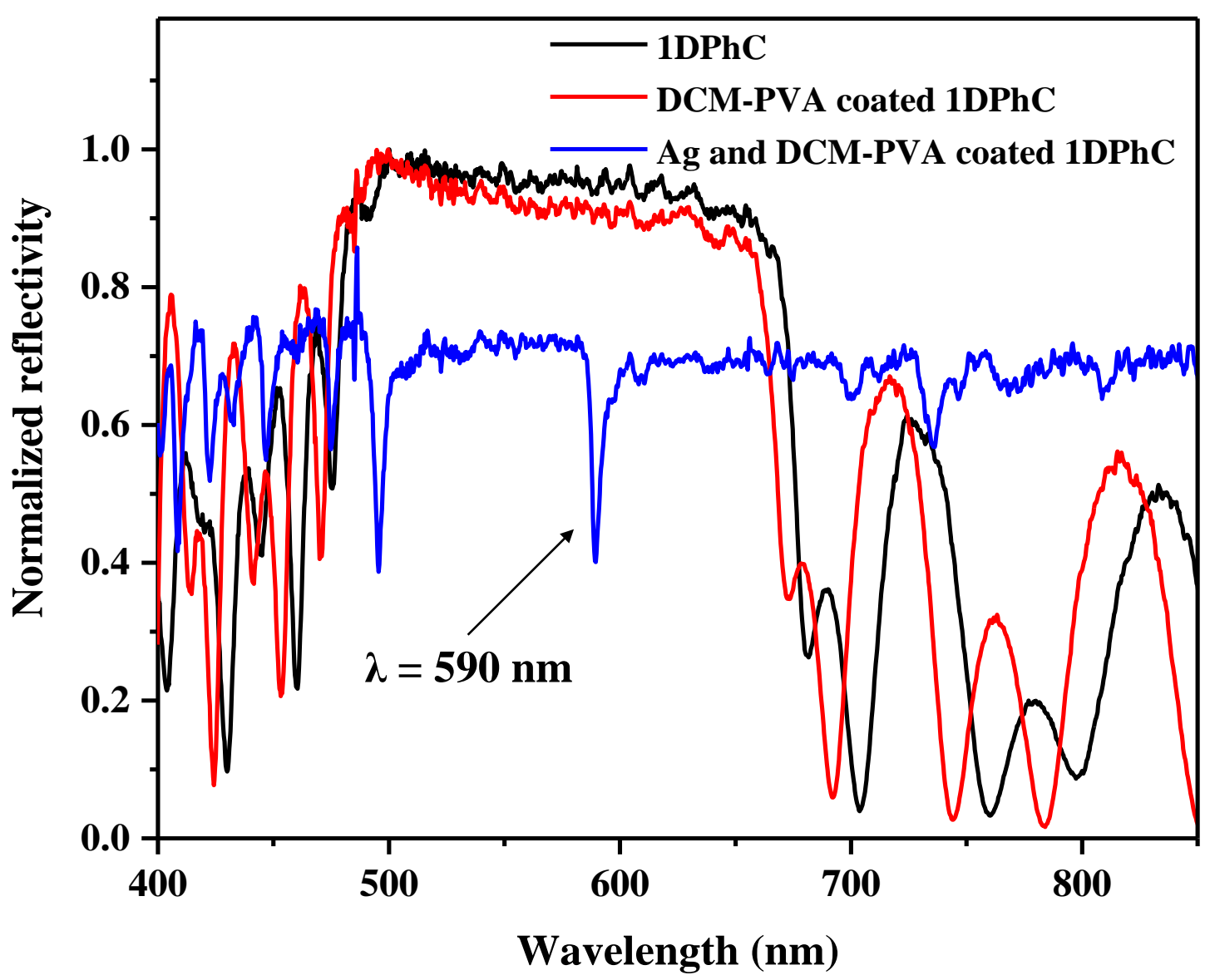
Field emission scanning electron microscope (FESEM) cross-section image of super-Tamm structure



- Average layer thickness of SiO₂ layer = 90 (± 4) nm
TiO₂ layer = 60 (± 4) nm
- Thickness of DCM doped PVA film ~ 600 nm
Ag thin film ~ 40 nm

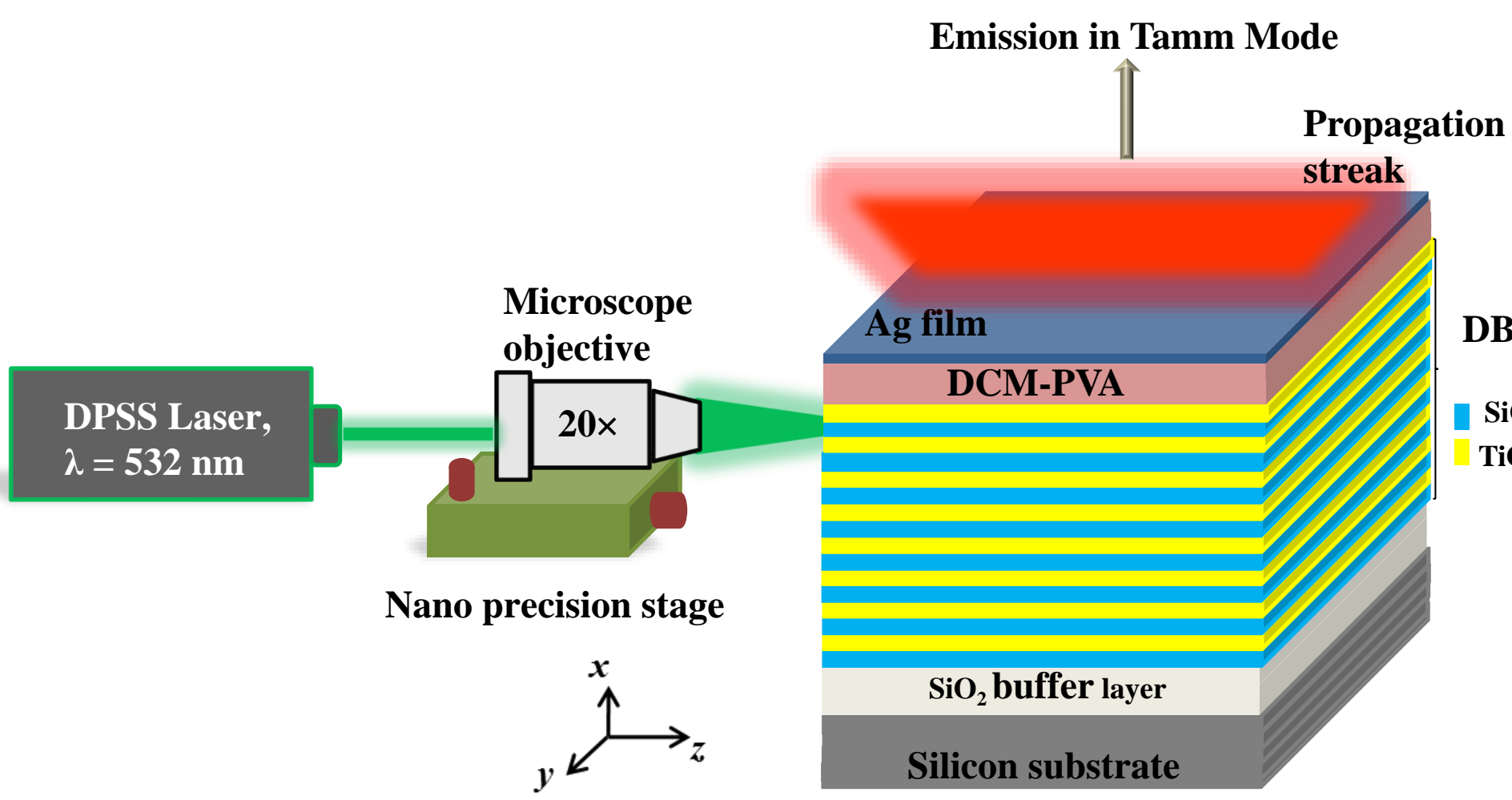
Experimental and Computational Studies

- Normal incidence reflection spectra of 1DPhC, DCM-PVA coated 1DPhC and Ag and DCM-PVA coated 1DPhC or super-Tamm structure (Experiment)
- Electric field intensity profile of the Tamm mode supported by super-Tamm structure (Transfer matrix computation)
- Emission spectrum of a super-Tamm structure recorded normal to the direction of excitation overlaid on corresponding reflection spectrum at normal incidence (Experiment)

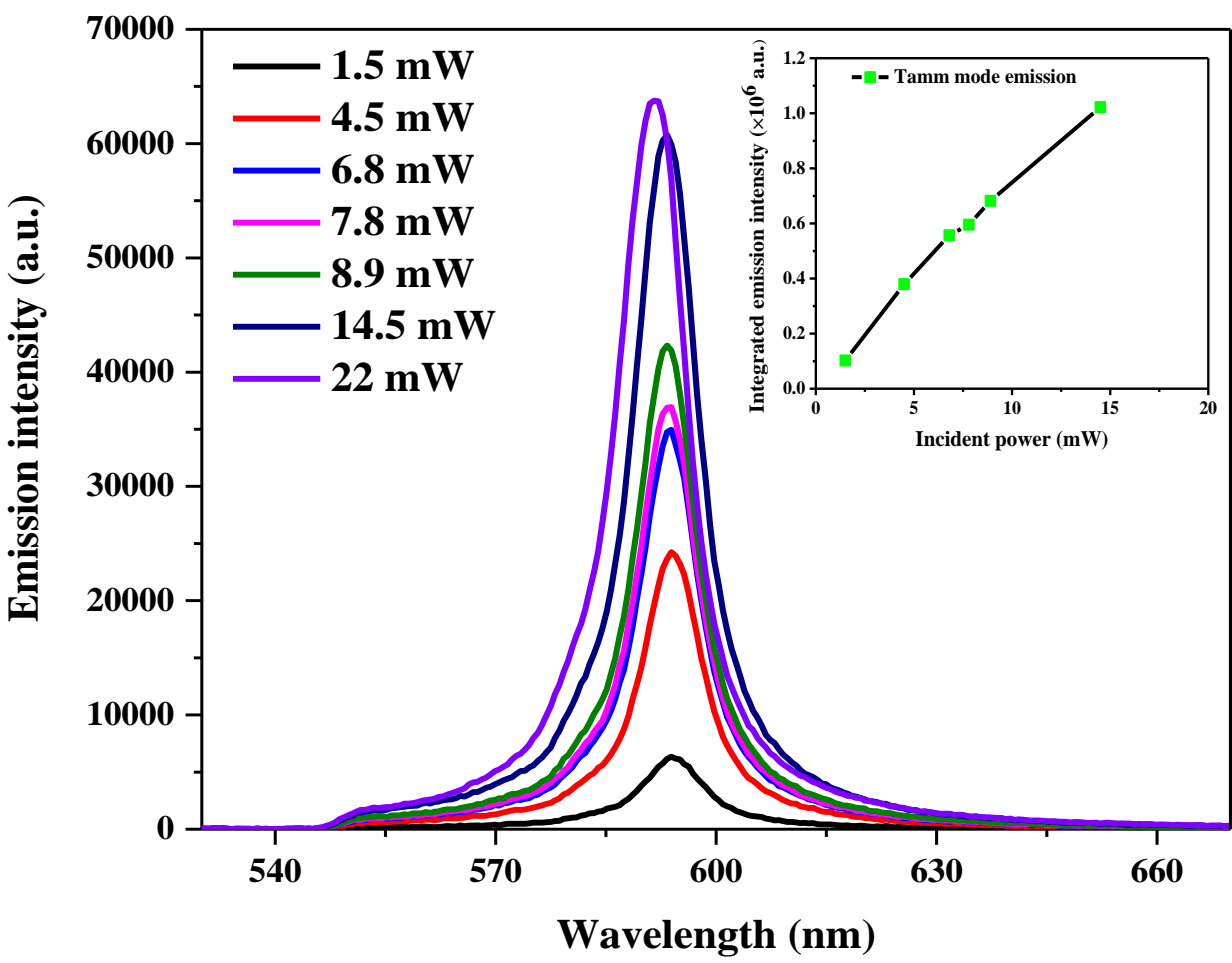


- A broad photonic stopband (PSB) is observed in the visible region from 460 nm to 680 nm, centered at λ_B = 590 nm.
- The super Tamm structure (Ag and DCM-PVA coated 1DPhC) exhibits a sharp resonance within the PSB at 597 nm, which corresponds to the Tamm mode of the structure.

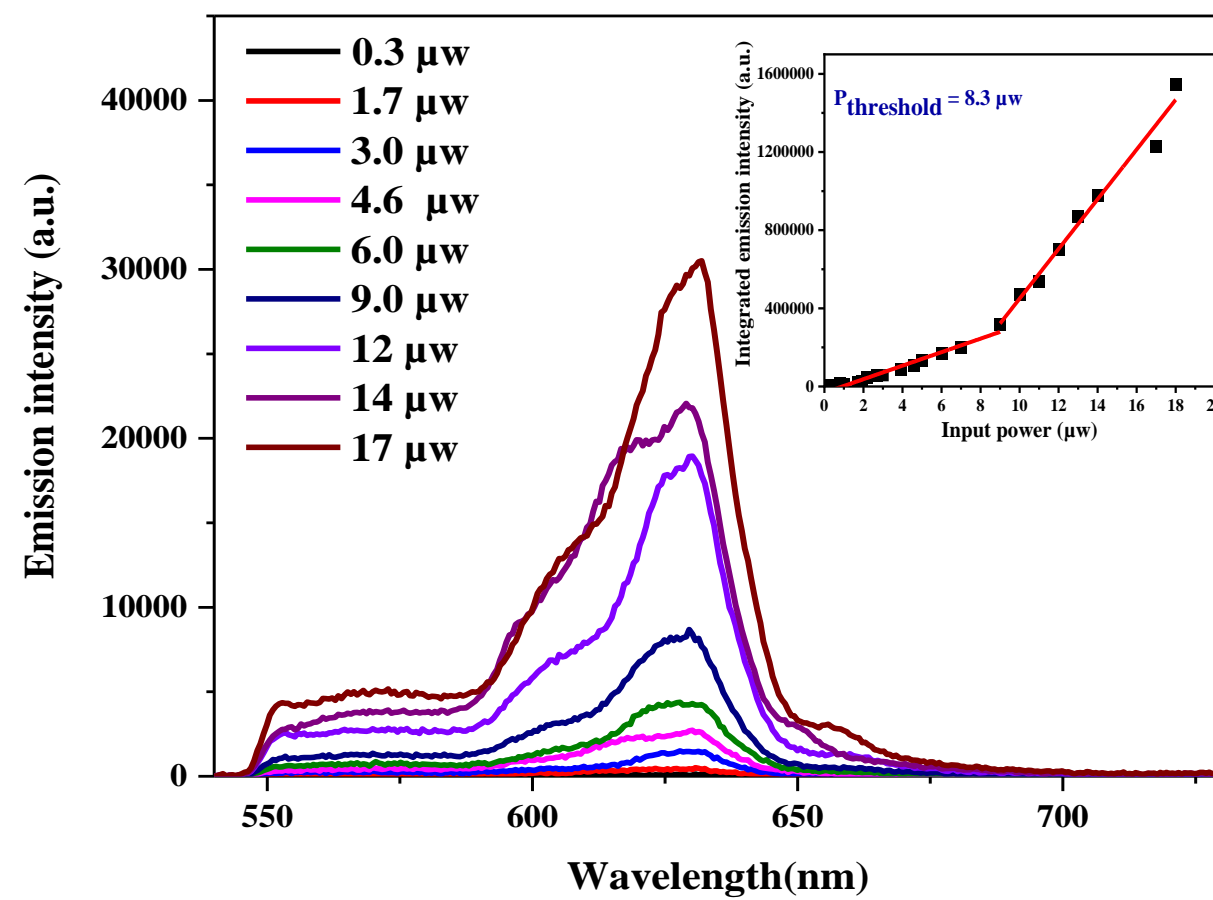
Schematic of the experimental set-up



Emission spectra of super-Tamm structure recorded normal to the direction of excitation for various pump powers, and pump power vs emission intensity plot (for CW laser, λ = 532 nm)



Lasing emission spectra of super-Tamm structure recorded normal to the direction of excitation for various pump powers, and pump power vs emission intensity plot (pulsed laser, λ = 532 nm, 0.5 ns at 1kHz)



- ### Conclusions
- One-dimensional photonic crystal super-Tamm structure was fabricated by depositing silver thin film on DCM dye doped PVA film coated 1DPhC structure.
 - The reflection spectrum was recorded over the one-dimensional photonic crystal super-Tamm structures shows the appearance of Tamm mode at 590 nm.
 - We have observed the spectral narrowing of Tamm aided amplified spontaneous emission (ASE) of the DCM dye with various pump powers for the fabricated super Tamm structure.
 - The possibility of lasing emission in one-dimensional photonic crystal super-Tamm structure is explored.

References

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