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On-chip infrared photonic waveguides excitation by quantum dots

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avec le Fonds européen de développement régional (FEDER)

We propose to integrate fluorescent semiconducting nanocrystals (PbS@CdS colloidal quantum-dots) as on-chip light source for waveguide excitation at 1550 nm.

Devices such as biosensors would greatly benefit from this concept as it would reduce the need for precise alignment

configuration of the input fiber array which is normally necessary, in configurations such as butt coupling or grating couplers that need to be carefully aligned and optimized.

As compared to on-chip technologies like VCSELs or other on-chip lasers, quantum dot sources are less technology demanding

and simply require an optical pumping beam much larger than a fiber. This concept is pursued in our European project GRACED.

Our main challenge is to harvest as many as possible fluorescent photons from the CoQDs and couple them into the guiding mode. To this end, we fabricate and test waveguide structures

with varied cumulative designs like spirals where CoQDs are encapsulated into the SiN waveguides. We compare their figure of merit vs the non-encapsulated versions. We show that encapsulation greatly enhances the coupling efficiency and that spiral waveguides circumscribed in a disk area filled with CoQDs appear to be an efficient design.



www.graced.tech

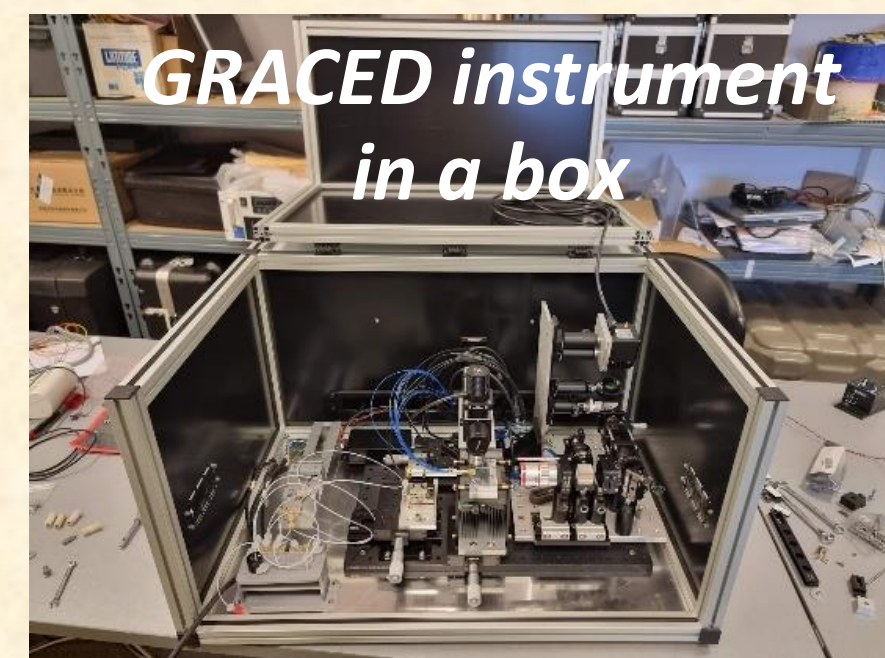
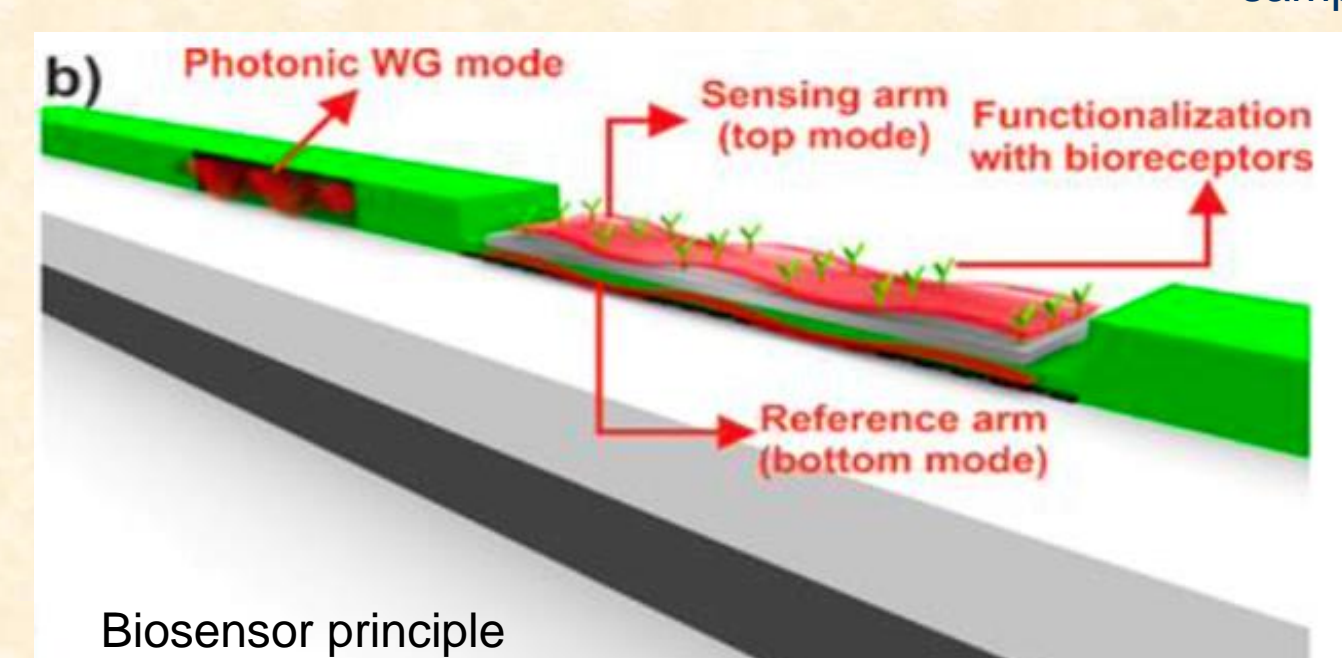
Ultra-compact, low-cost plasmo-photonic bimodal multiplexing sensor platforms as part of a holistic solution for food quality monitoring. Coordinator : Cyprus Research Centre (CYRIC)

Objective : Develop a novel ultra-compact, cost-effective, plasmo-photonic bimodal sensor platform with on-chip light generation suitable for farm-to-fork applications

- Detect simultaneously different contaminants
- Validate through real-world pilots
- Develop a portable instrument for laboratory & field analysis of all types of samples

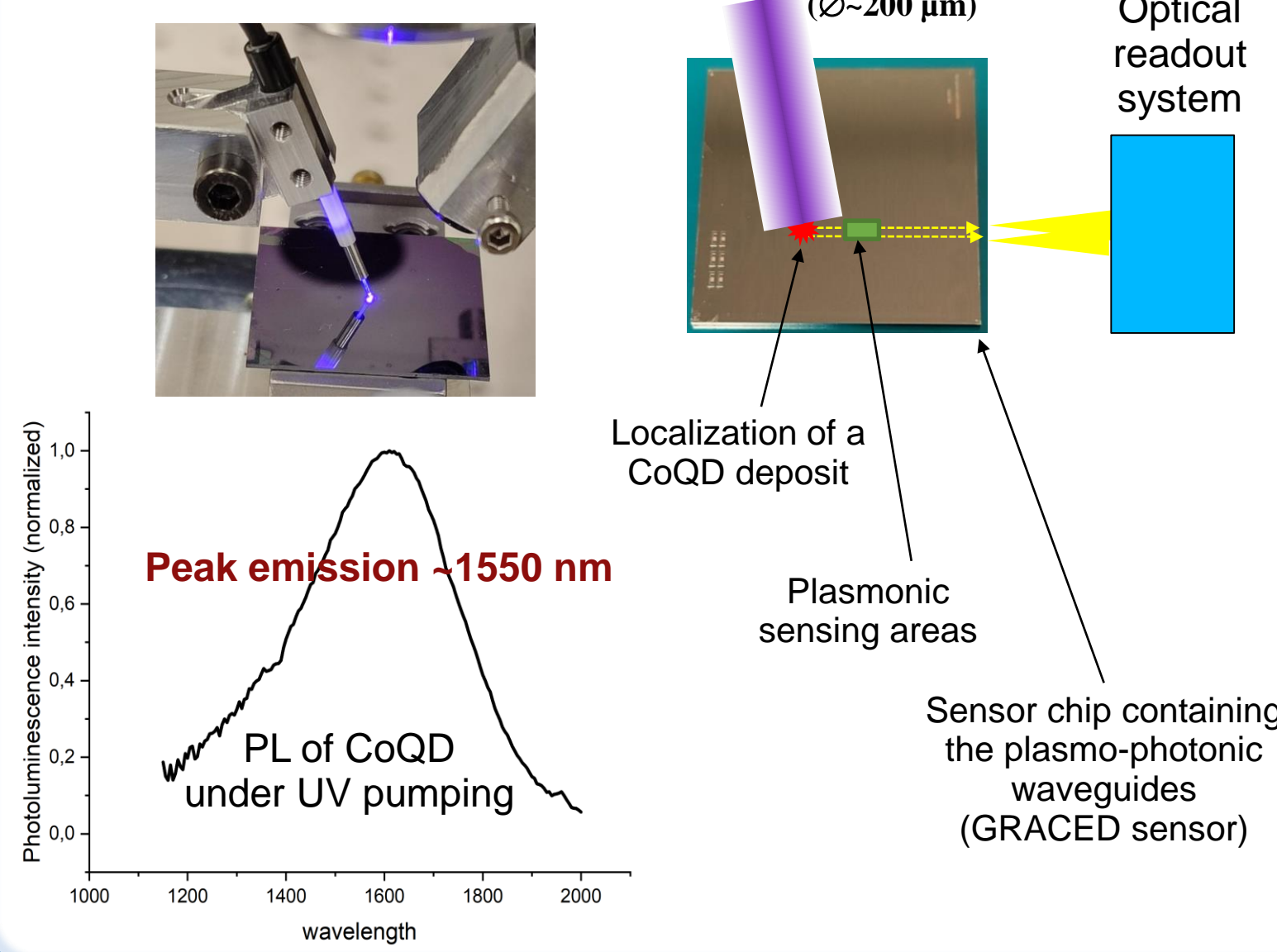
targeted analytes :

- ✓ Ochratoxin A
- ✓ Deoxyvalenol
- ✓ Aflatoxin B2
- ✓ Escherichia coli O157
- ✓ Salmonella
- ✓ Imidacloprid
- ✓ Acrylamide



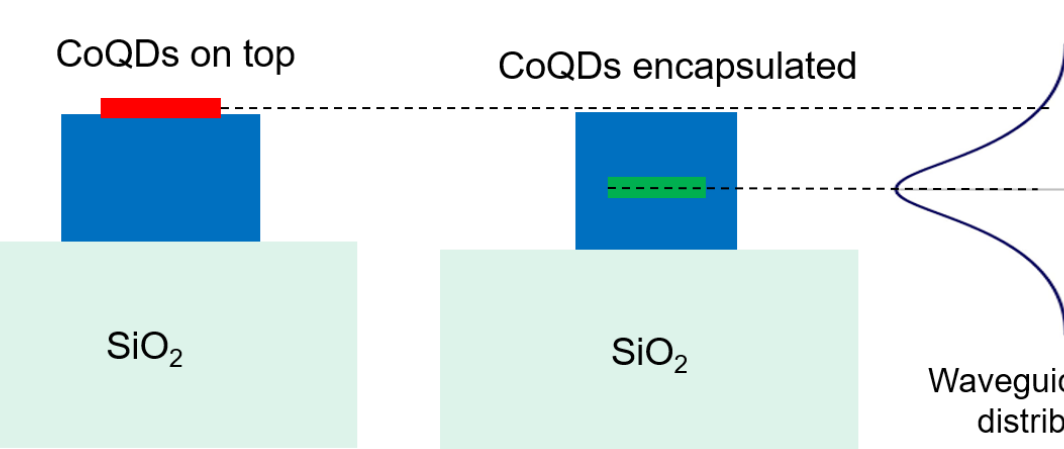
✓ A single-arm plasmo-photonic MZI on SU8 or SiN platform

Concept



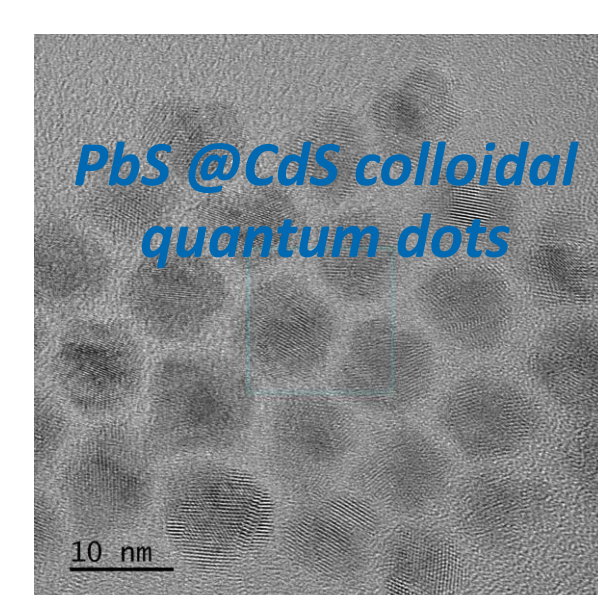
➢ CoQDs emit omni-directionally.

➢ To optimize the coupling of luminescent photons into a waveguide structure, one needs to increase the LDOS of the waveguide structure in the vicinity of the CoQDs.

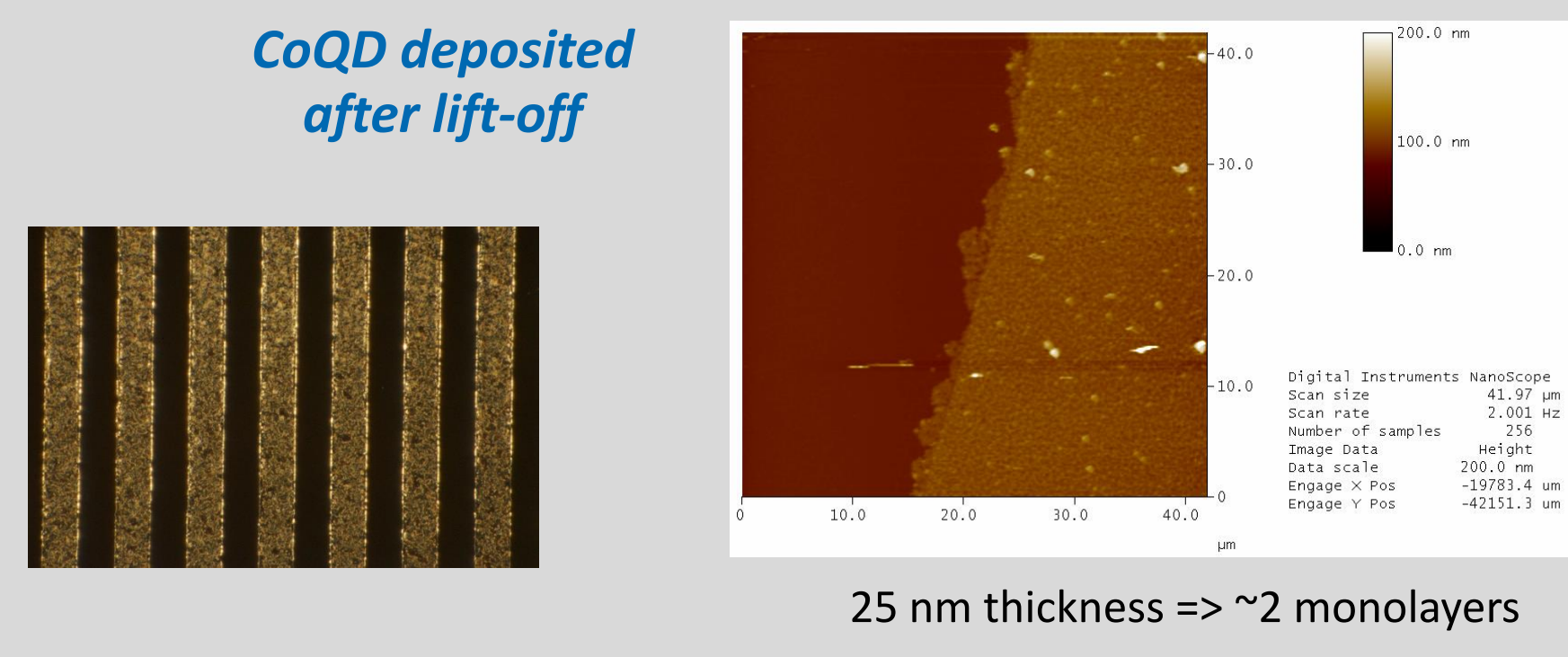


➢ To this end, the encapsulated CoQDs configuration is more favorable than the on-top (or bottom) configuration.

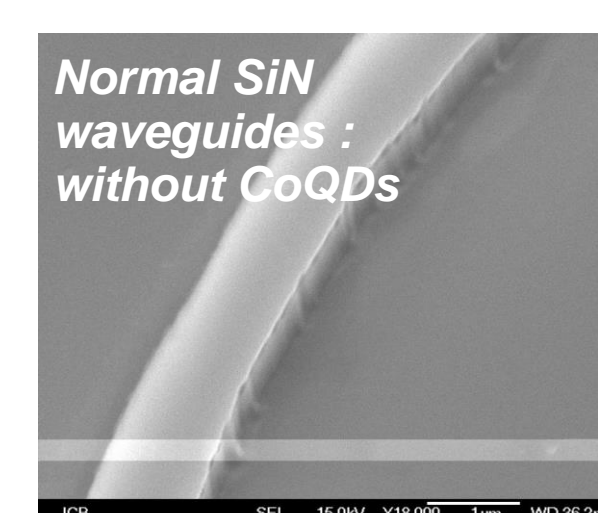
Fabrication



HR-TEM image

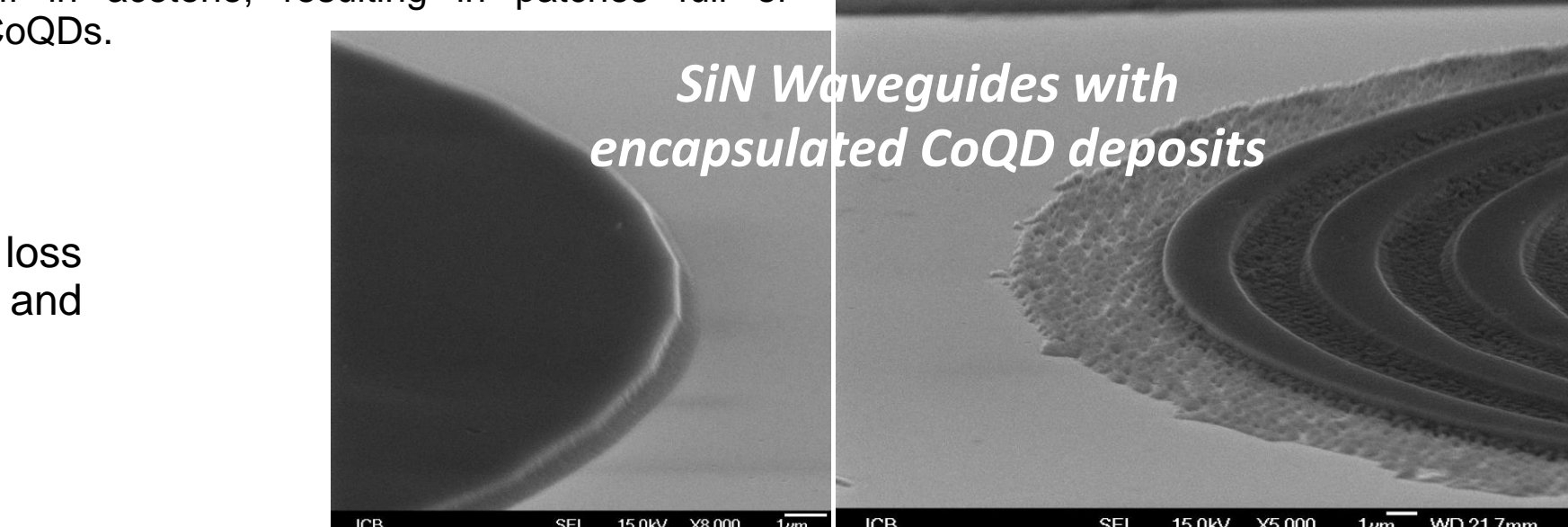


CoQD are deposited by spin-coating from a suspension in a volatile solvent, followed by lift-off in acetone, resulting in patches full of CoQDs.



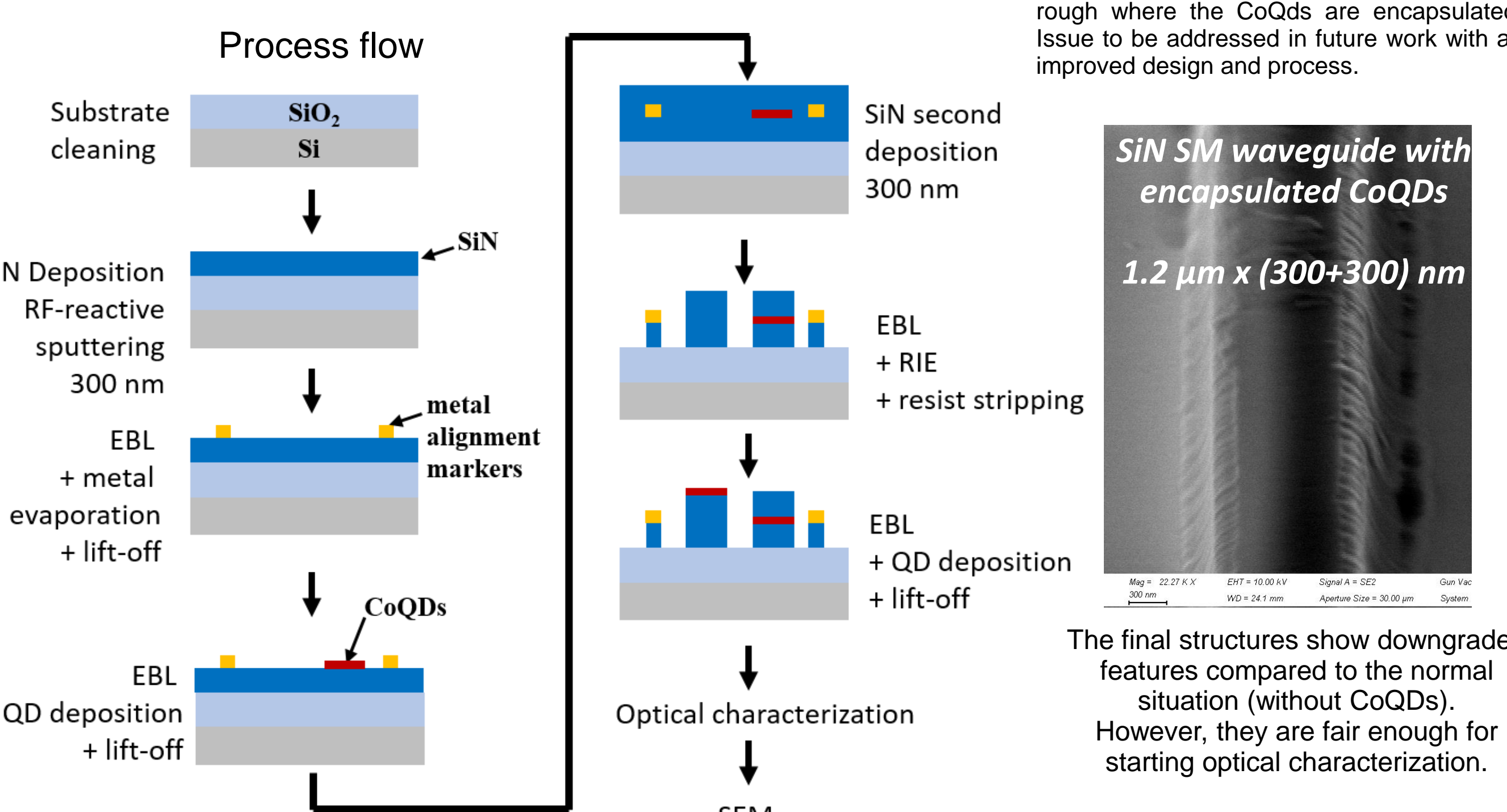
Normal SiN waveguides : without CoQDs

propagation loss between 1,5 and 2 dB/mm



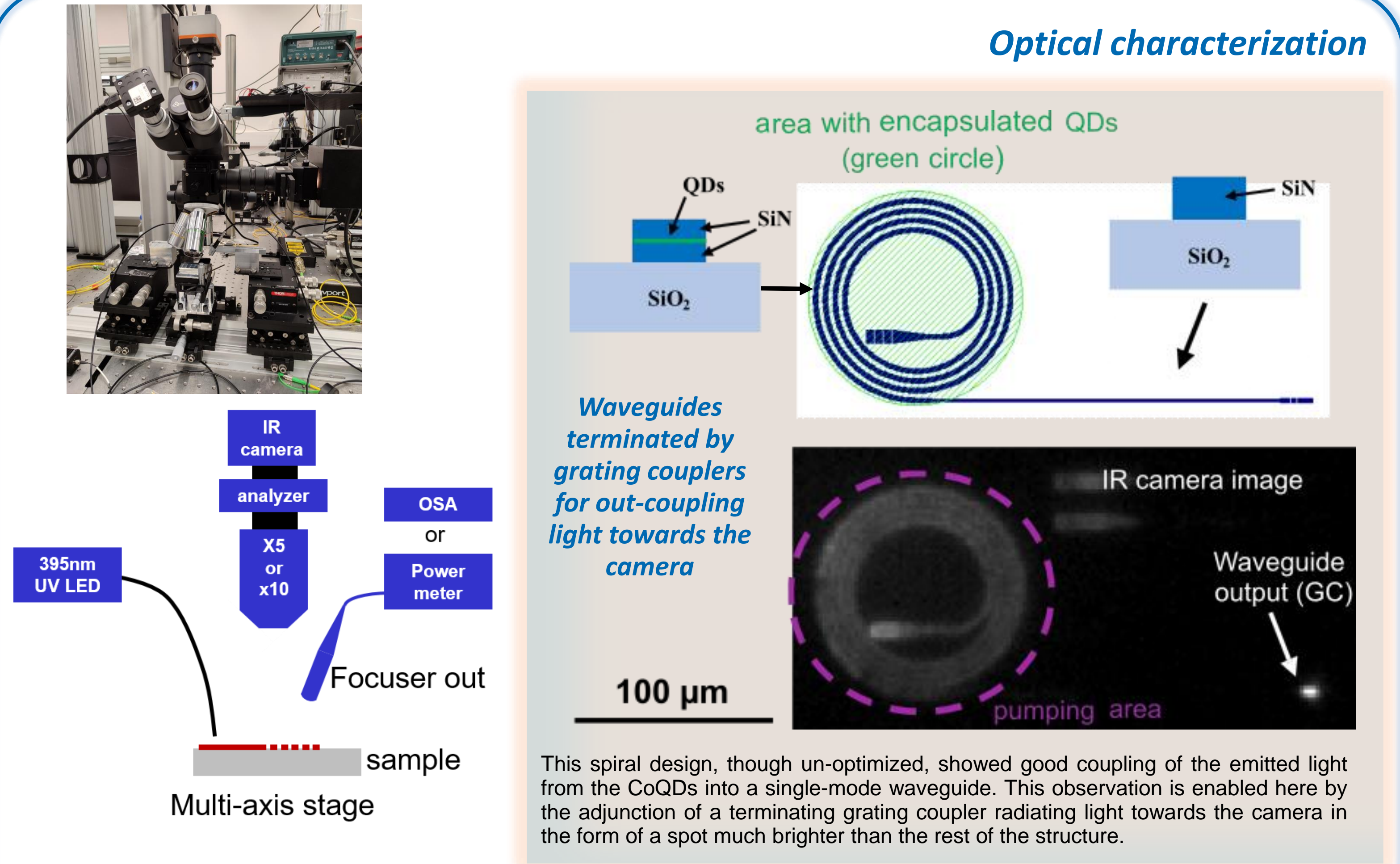
SiN Waveguides with encapsulated CoQD deposits

Micromasking effect : etched SiN appears rough where the CoQDs are encapsulated, issue to be addressed in future work with an improved design and process.



The final structures show downgraded features compared to the normal situation (without CoQDs). However, they are fair enough for starting optical characterization.

Optical characterization



This spiral design, though un-optimized, showed good coupling of the emitted light from the CoQDs into a single-mode waveguide. This observation is enabled here by the adjunction of a terminating grating coupler radiating light towards the camera in the form of a spot much brighter than the rest of the structure.

For the purpose of a quantitative analysis, we studied planar disc waveguides in which CoQDs are contained within an inner disc. PL photons are coupled into the larger disc which is the planar waveguide. In the end, the guided photons are scattered by the rim of the outer disc and their intensity can be measured with the camera.

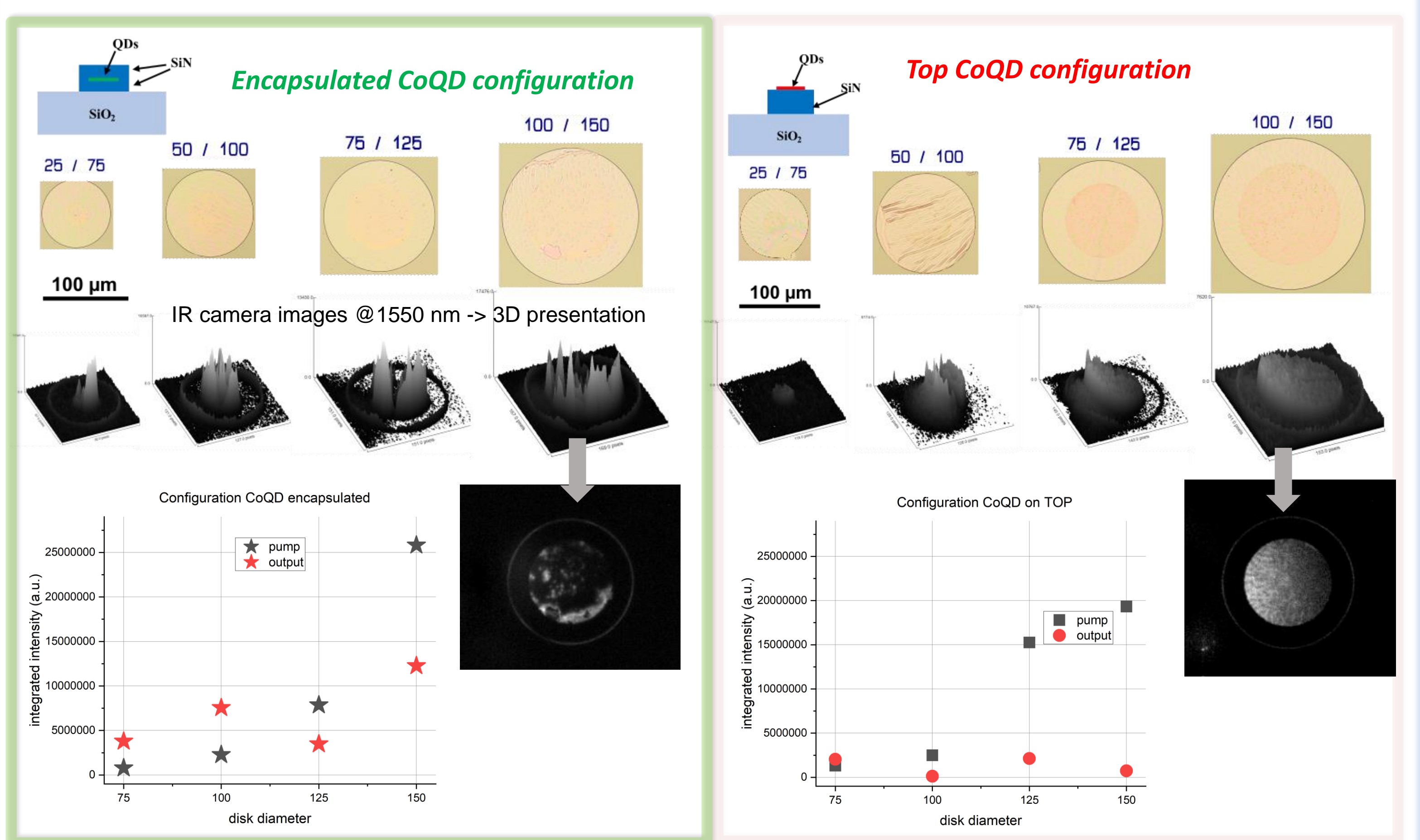


Figure of Merit 1

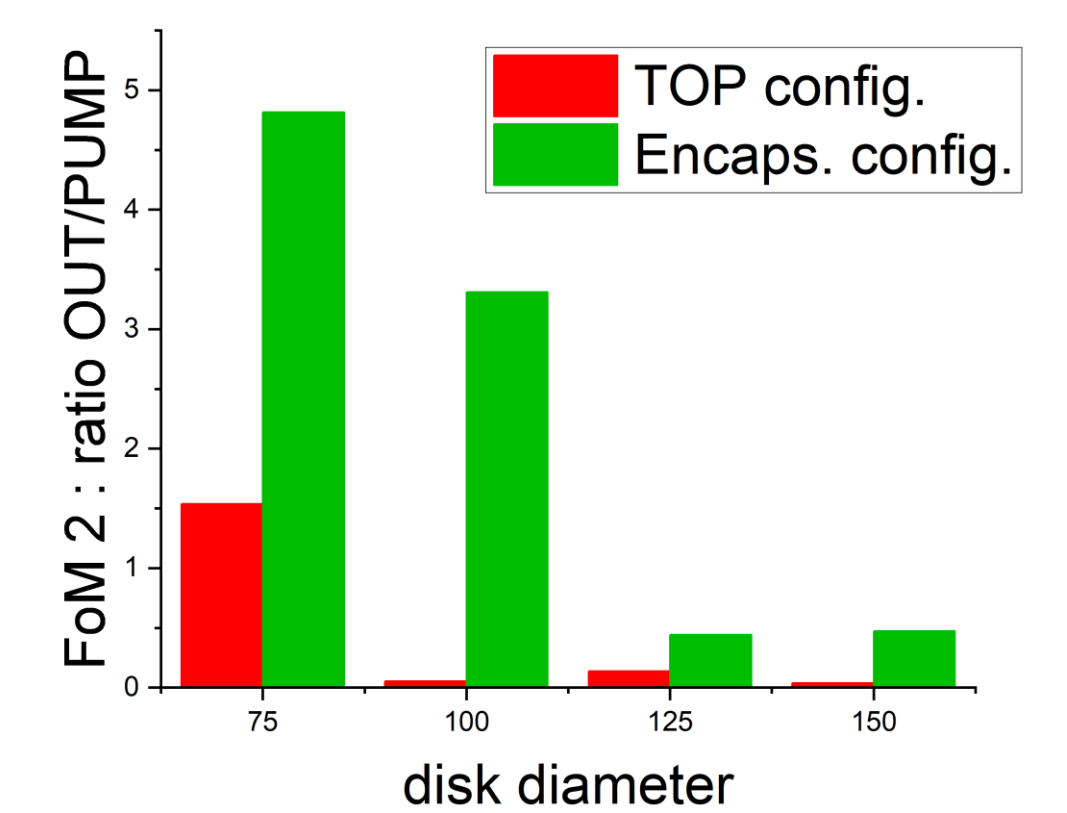
DISKS	Encaps/Top
25/75	1,9
50/100	57,1
75/125	1,6
100/150	16,7

FoM1 = Ratio of integrated intensities Encaps. Vs TOP

Figure of Merit 2

RATIO OUT/PUMP	TOP	ENCAPS	"gain"
25/75	1,539325707	4,81775815	3,1
50/100	0,052846759	3,31047023	62,6
75/125	0,139057683	0,44210619	3,2
100/150	0,038002316	0,47512648	12,5

FoM2 = Out/pump ratio of integrated intensities



Comments

Both figures of merit 1 and 2 clearly show the advantage of encapsulating the QDs. Despite important variability due to fabrication issues, they are always largely in favor of encapsulation with a factor of gain varying between 3 and 62 for FoM2.

Perspectives

This initial study confirmed the viability of our concept. Much progress is expected in the follow-up work by improving both the design and the waveguide geometry after fabrication. Improvement of the fabrication process is currently in progress. This will then allow us to combine this local excitation scheme with plasmo-photonic waveguide sensors.

Funding

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Acknowledgement

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- [3] D. B. Dement et al., ACS Appl. Mater. Interfaces, 11 (2019) 14970-14979

