Combination of optical μ-transmission and μ-photoluminescence techniques for local characterization of rare earth doped glass μ-spheres

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Outline

- Introduction and motivation
- Experimental details
- μ-transmission and μ-PL results
- Spectral dependence of the Q-factors
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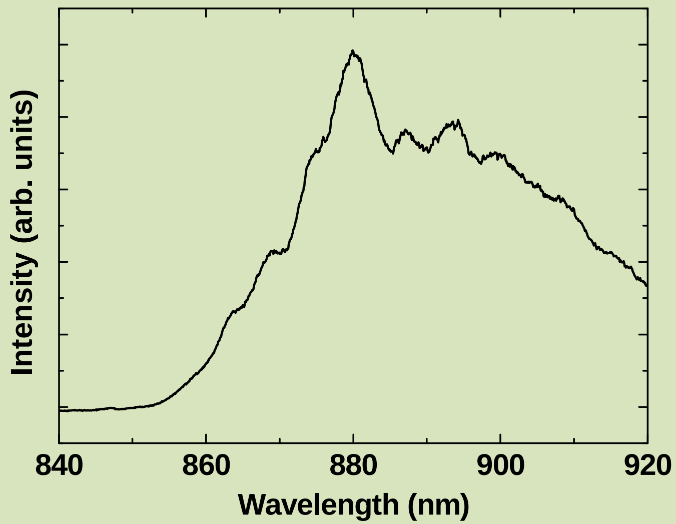
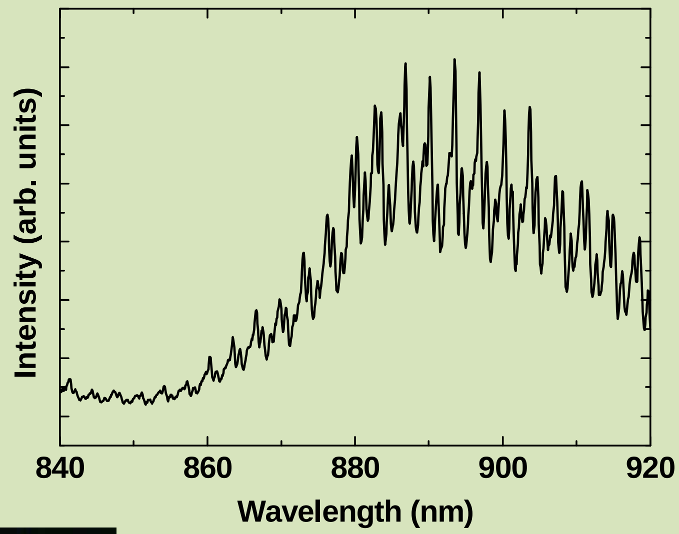
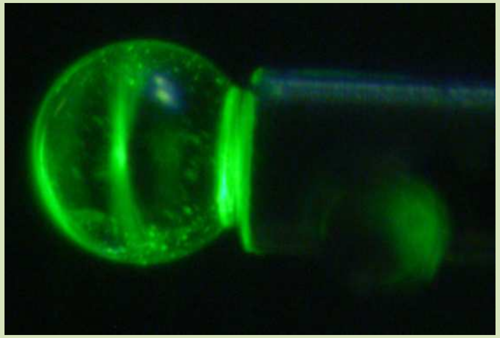
Introduction

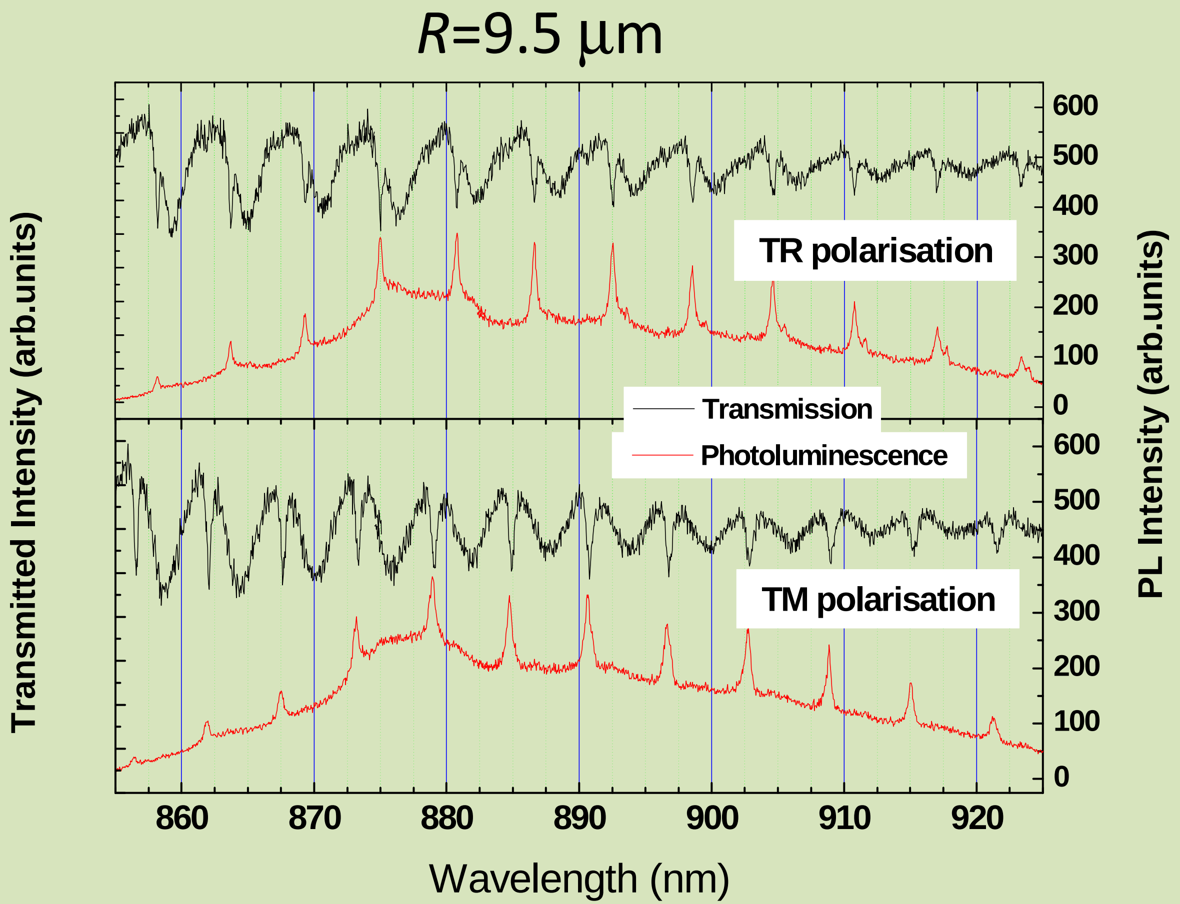
Effect of modulation in the emission of the Nd^{3+} : $^4F_{3/2} \rightarrow {}^4I_{9/2}$ produced by the microsphere.







Motivation



A. Ashkin and J.M. Dziedzic. Applied Optics **20** (1981) 1803-1814

Motivation

Combine transmission and PL measurements on light emitting micro-spheres because of their complementarity.

It is unlikely to produce perfect spheres, most probably obtaining spheroid shapes $\rightarrow$ WGM spectral positions depend on the specific normal vector angle of the optical trajectory.

Solution: **Reduce the region of observation and share the collection scheme for both techniques.**

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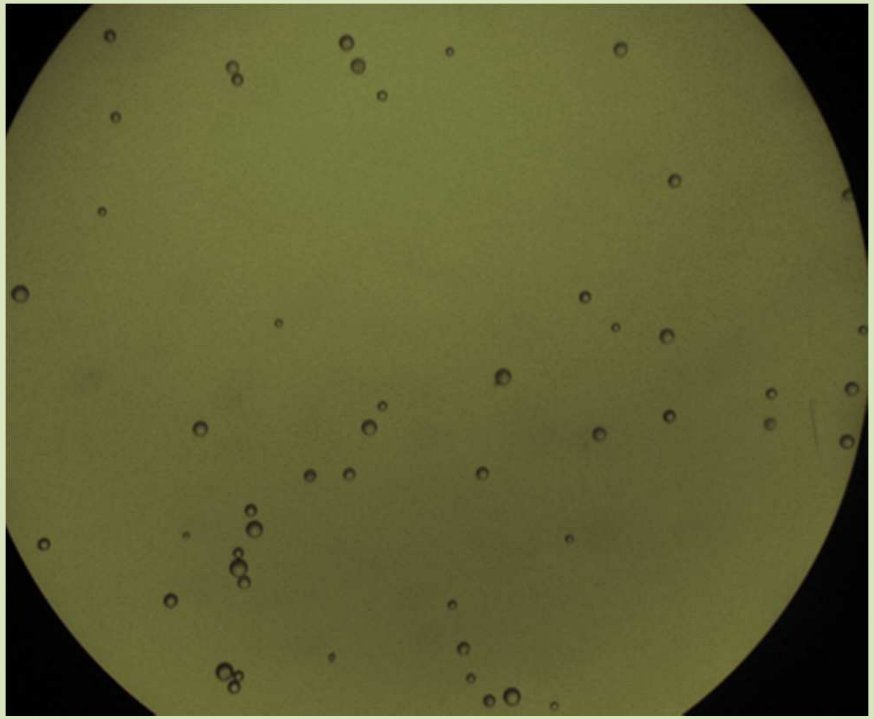
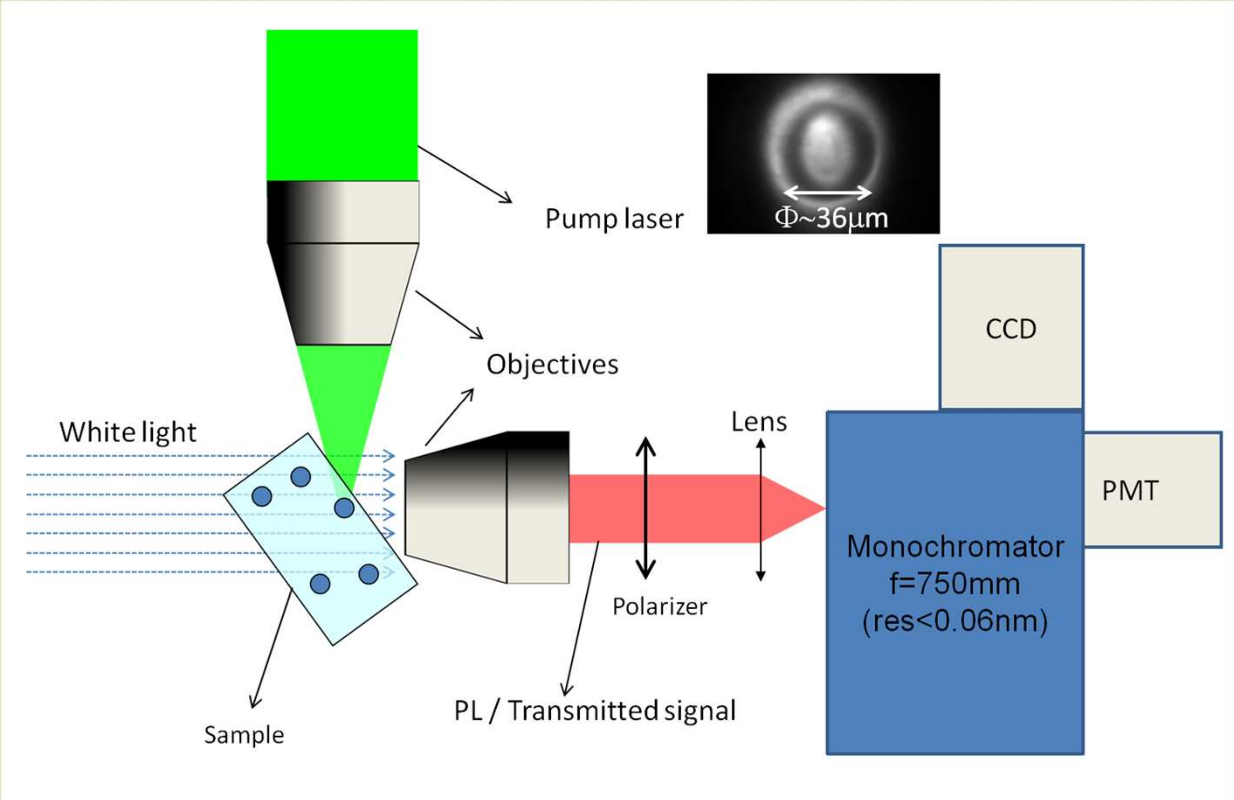
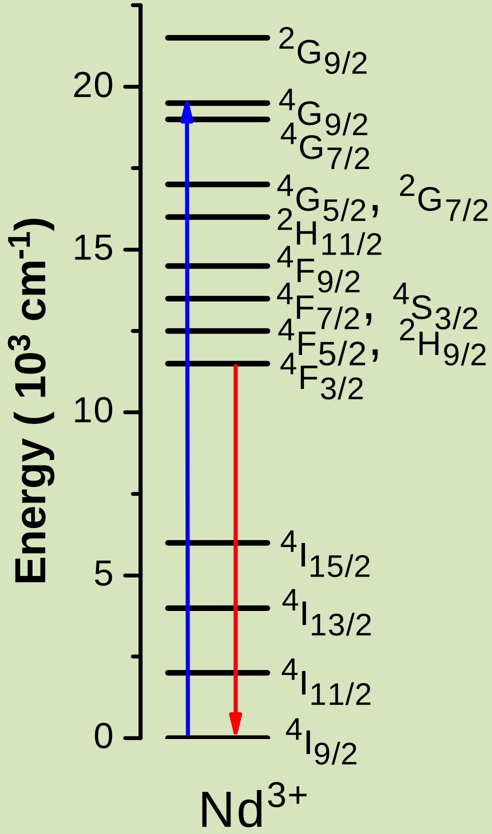
Sample's production

- Precursor material: Nd^{3+} -doped bulk borate glass.
- Spheres produced by the method of G. R. Elliot et al. (Opt. Express, 15 (2007))
- This method produces microspheres of various sizes (20-60 µm).
- Precursor glass and spheres are both produced at ULL.



Experimental setup





CW laser at 514 nm (Ar^+ laser) as pump source resonant to the Nd^{3+}:$^4I_{9/2}\rightarrow{}^4G_{9/2}$ absorption transition. The observed emission band was that associated to the Nd^{3+}:$^4F_{3/2}\rightarrow{}^4I_{9/2}$ transition.

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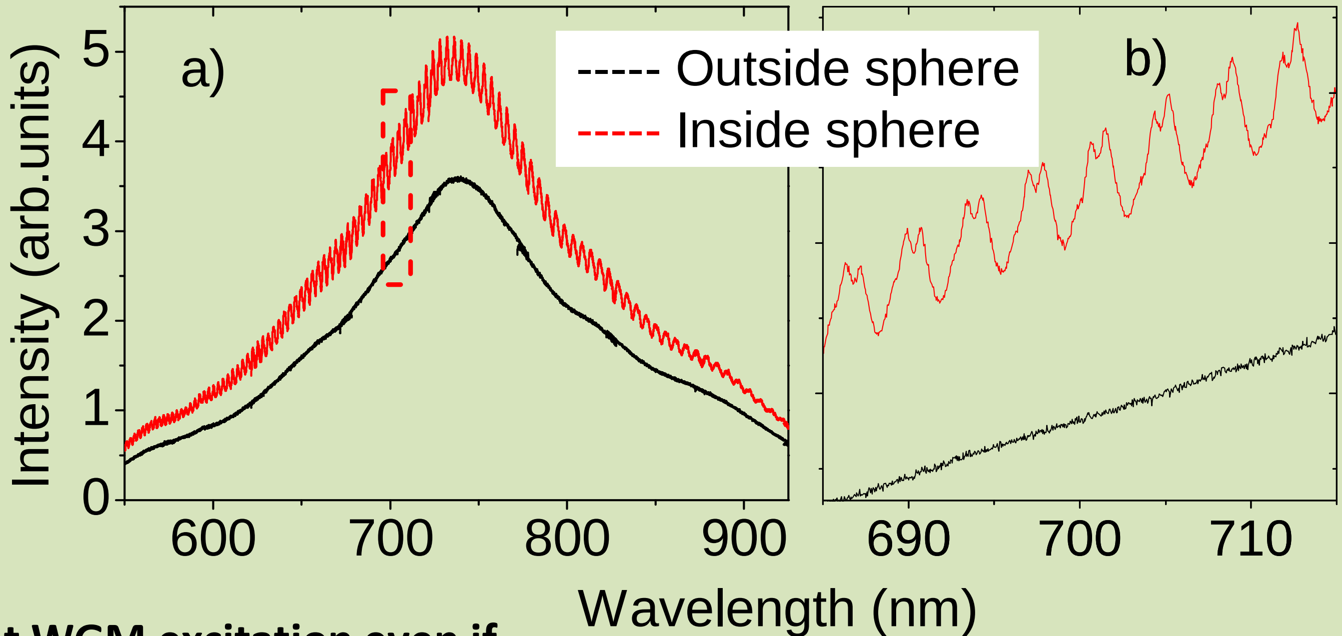
Transmission on a single sphere

R=18 μm on the CCD



- **Efficient WGM excitation even if the incident beam is in free space.**

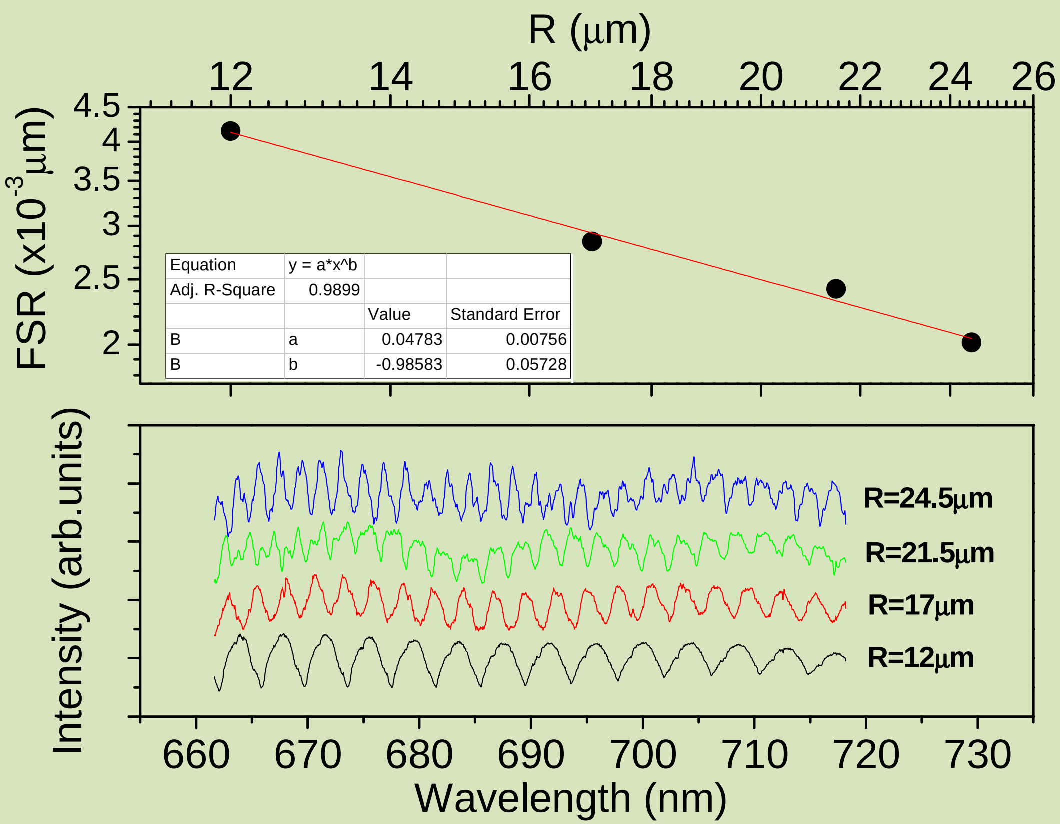
- **Oscillatory-like behavior**

- FSR for the oscillating signal of about 3.73 nm. FSR for the WGM of about 3.62 nm.

- If we define the ratio among those two FSR as Γ_{FSR} then, for this experimental case, $\boldsymbol{\Gamma_{FSR}}$ **=1.03.**

A. Serpenguzel et al. J. Opt. Soc. Amer. **B14** (1997) 790-795

FSR of the oscillating signal vs R



A *1/R* behavior is extracted from the fit of the FSR vs R

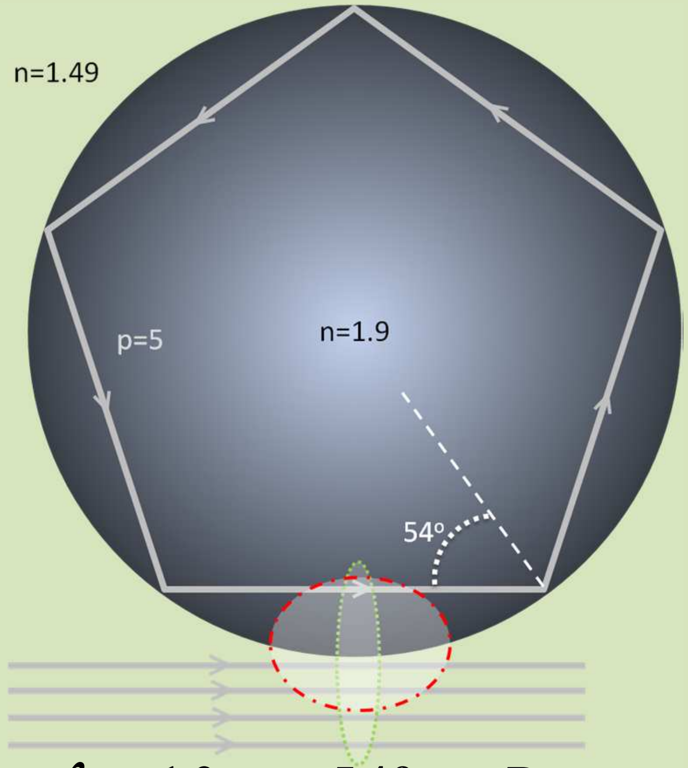
Clear indication of an interference phenomenon involving light propagating within the microsphere

Model for explaining the origin of the oscillating–like signal

- Experimentally Γ_{FSR}~1.03, which is close to what given theoretically by a trajectory with *p*=5 $\Gamma_{FSR}=1.07$

$$FSR_{WGM} = \frac{\lambda^2}{2\pi n_{eff} R}$$

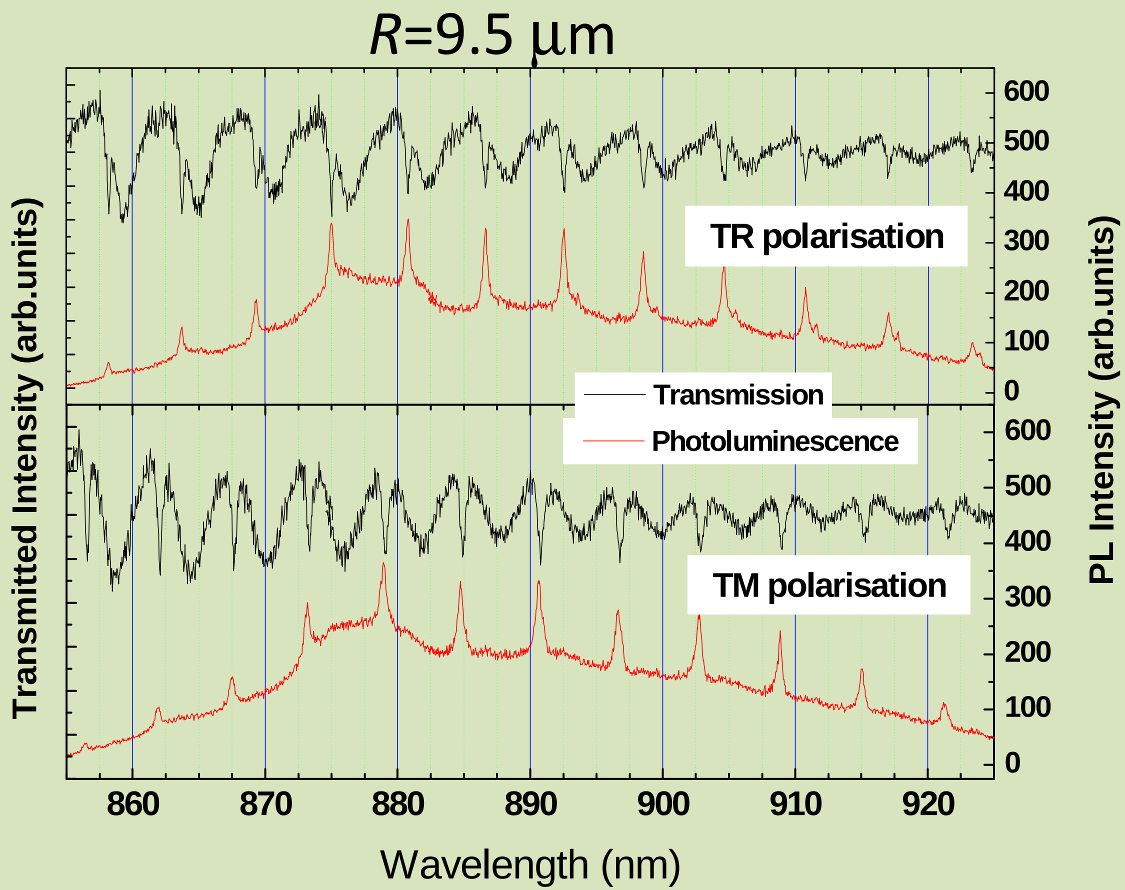
$$\Gamma_{FSR} = \frac{2\pi n_{eff}}{p\, n_{sp} \sin\frac{\pi}{p}}$$



$$m\lambda = 10\cos 54^{o}\, n_{sp} R$$

$$FSR = \frac{\overline{\lambda}^2}{10\cos 54^{o}\, n_{sp} R}$$

μ-PL vs μ-transmission



Remarkable agreement in the WGM spectral positions showed by both techniques for both polarizations.

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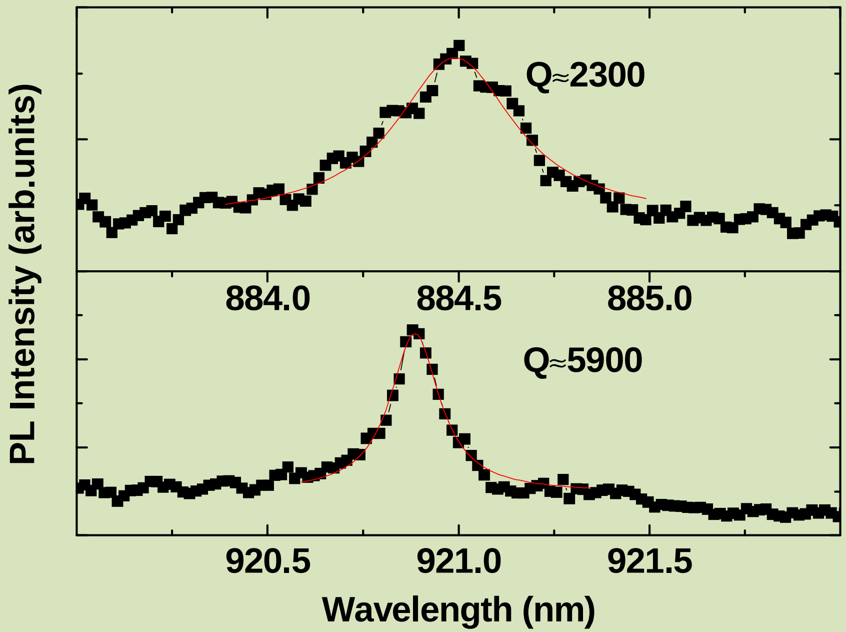
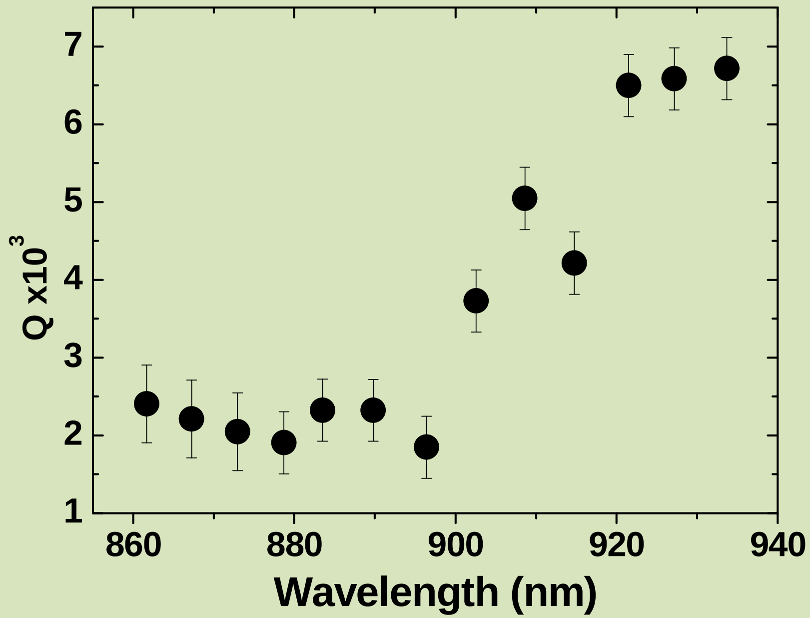
Spectral dependence of the Q-factors

TM polarized resonances for a μ-sphere of R=9.5μm.





Q factors in this spectral region are dominated by absorption losses of the material with a maximum around 880 nm.

$$Q = \frac{\lambda}{\Delta\lambda}$$

$$Q^{-1} = Q_{mat}^{-1} + Q_{surf}^{-1} + Q_{curv}^{-1} + Q_{coupl}^{-1}$$

Conclusions

- **μ-transmission** allows significant WGM coupling efficiency even if the external beam is in free space.

- Comparison among **μ-PL** and **μ-transmission** demonstrated their consistency and complementarily.

- **μ-transmission:** Provides information about the material in its fundamental state and on the absence of local heating. Presence of an oscillating signal provide further information about the radius of the microspheres, if its material refractive index is known.

- **μ-PL:** Provides much more intense WGM signal contribution and allows testing some of its active properties and potentialities, e.g. degree of material population inversion, lasing action, optomechanical features, etc.

Thank you !!