Coated microresonators for photonics applications

Davor Ristić[1], Alphonse Rasoloniaina[2], Andrea Chiappini[3], Patrice Féron[2], Stefano Pelli[4], Gualtiero Nunzi Conti[4], Mile Ivanda[1], Giancarlo C. Righini[5], Gilles Cibiel[6], and Maurizio Ferrari[3]

[1]Institut Ruđer Bošković, Bijenička cesta 54, 10000 Zagreb, Croatia
[2]FOTON-Systèmes Photoniques (CNRS-UMR 6082), ENSSAT, 6 rue de Kerampont, CS 80518, 22305 Lannion cedex, France.
[3]IFN – CNR CSMFO Lab., Via alla Cascata 56/C Povo, 38123 Trento, Italy
[4]IFAC - CNR, MiPLab., 50019 Sesto Fiorentino, Italy
[5]Enrico Fermi Centre, Piazza del Viminale 1, 00184 Roma, Italy
[6]Centre National d'Etudes Spatiales (CNES), 31401 Toulouse Cedex 9, France

Outline

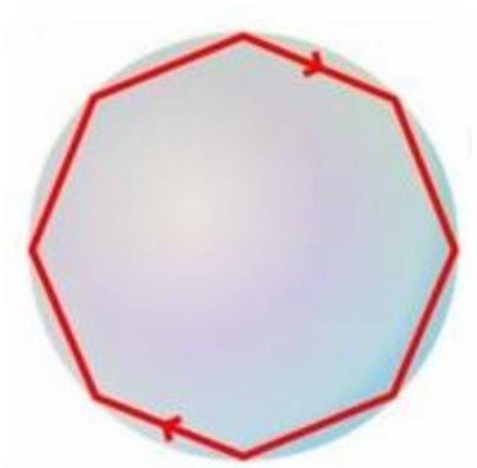
- Spherical microresonators

- Coating of spherical microresonators

- Applications:
  - sensing
  - lasing and wavelength selective amplification
  - modal dispresion tailoring

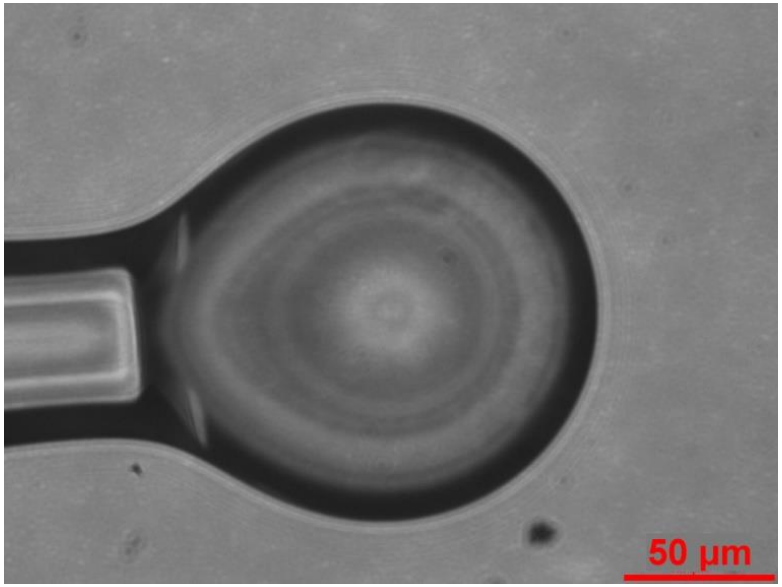
Spherical microresonators

Light confinement via total internal reflection



The modes are called whispering gallery modes

Spherical symettry –modes have *n,m,l*

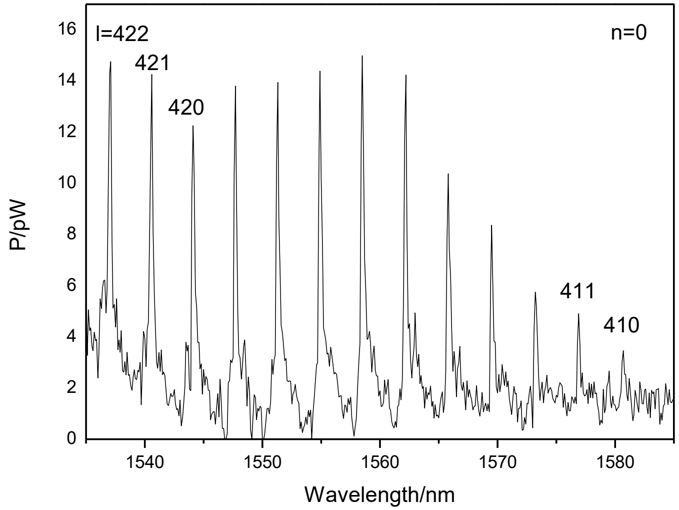


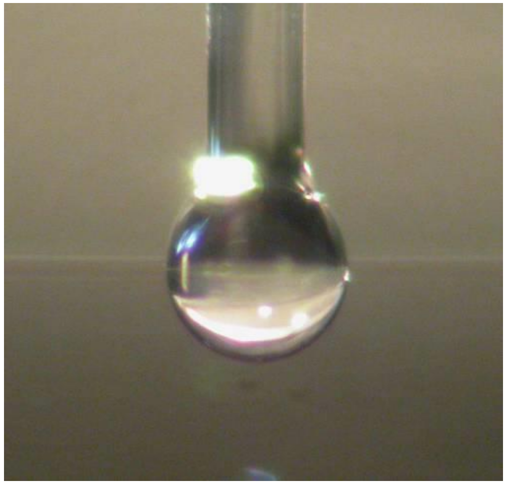
High Q-factor (10^6-10^9), Low mode volume (λ/n)

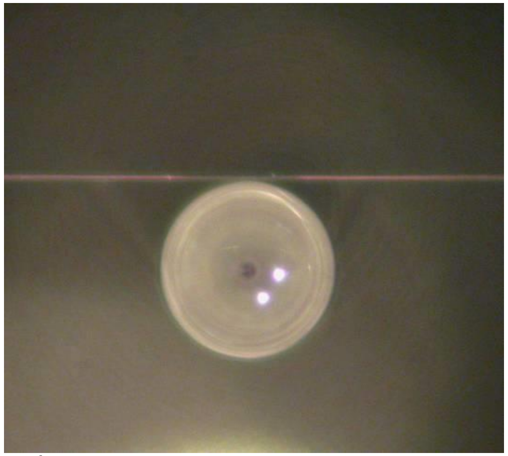
Applications:

- Non-linear optics (FWM, freqency combs)
- Lasing
- Sensing
- QED (single photon sources)

Coupling via a tapered fibre



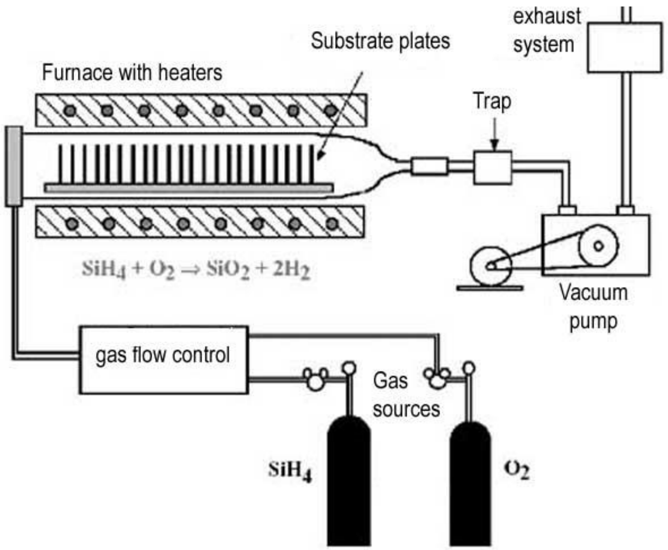




D. Ristić, A. Rasoloniaina, A. Chiappini, P. Féron, S. Pelli, G. Nunzi Conti, M. Ivanda, G. C. Righini, G. Cibiel, and M. Ferrari, About the role of phase matching between a coated microsphere and a tapered fiber: experimental study, Optics Express, 21, 20954-20963 (2013)

Coating of spherical microresonators: Low Pressure Chemical Vapor Deposition

- Thermal pyrolisis of silane $SiH_4 \rightarrow Si + 2H_2$
- Highly homogenous films on arbitrary shaped surfaces
- Good surface quality (low roughness)



Coating of spherical microresonators: sol-gel

TEOS + EtOH

H_2O + HCl

refluxed
1 h, 65 °C

Pre-hydrolized TEOS solution

$HfOCl_2 \bullet 8H_2O$ + EtOH

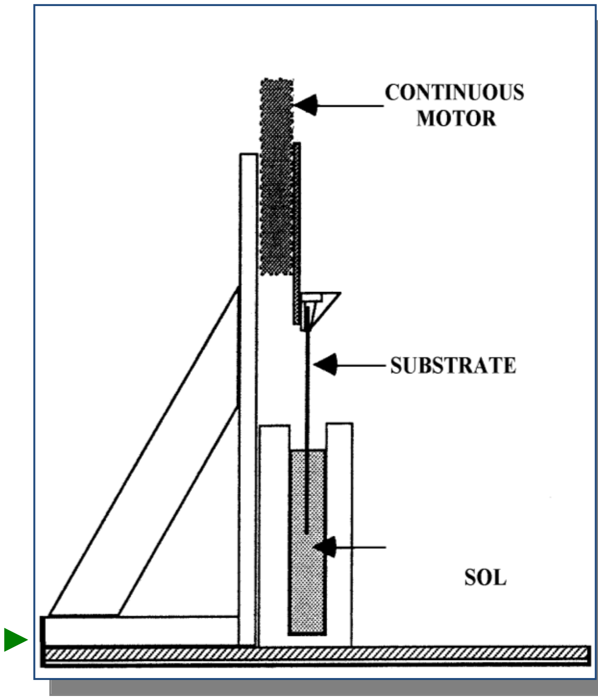
70 SiO_2 – 30 HfO_2

0.3 % mol Er^{3+}

$Er(NO_3)_3\ 5H_2O$

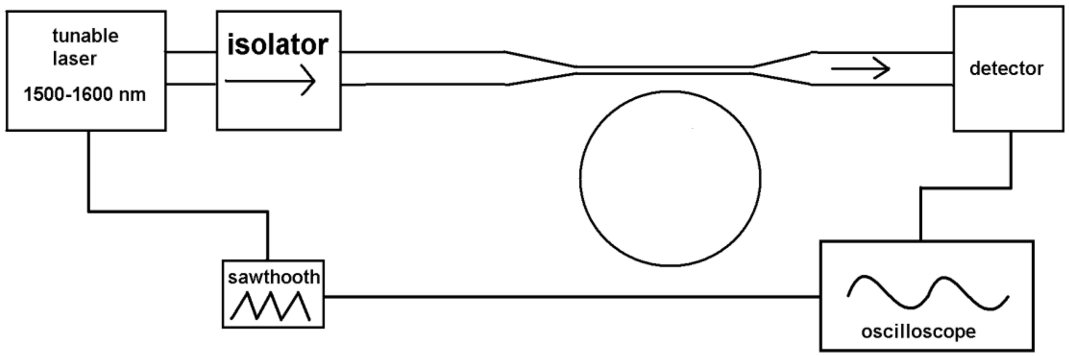
Aging 16 h at R.T.

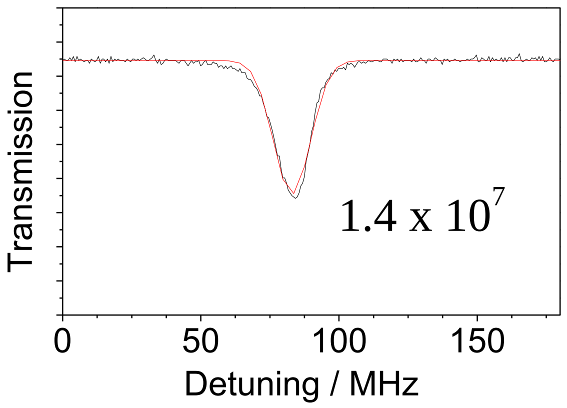
dip-coating

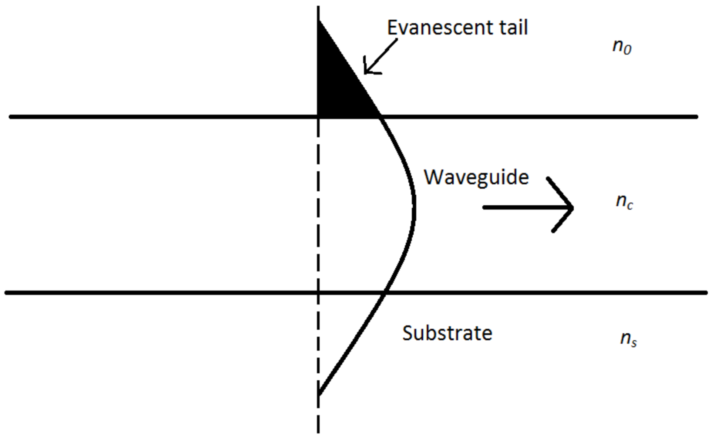


50'' at 900 °C after each dip.
2 min after each 10 dips
A heat treatment of 900 °C for 5 min after 30 dips.

Application: sensing

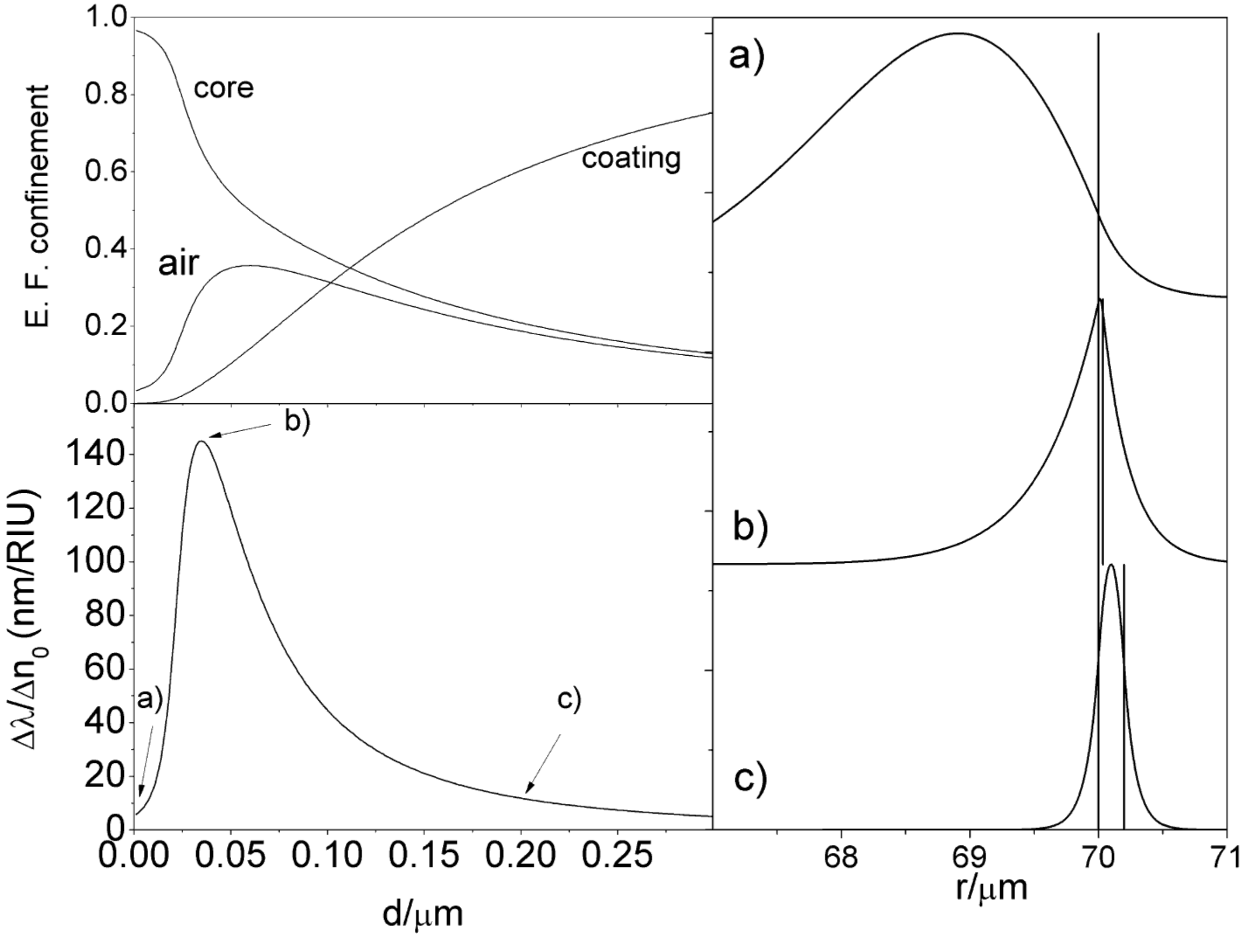






The binding of a analyte to the surface leads to the change of n_0

The change on n_0 leads to a shift of the detection peak



Coating with silicon can increase the sensing sensitivity of a microsphere very much

By changing the thickness of a coating we can induce a strong increase of the evanescent field strength

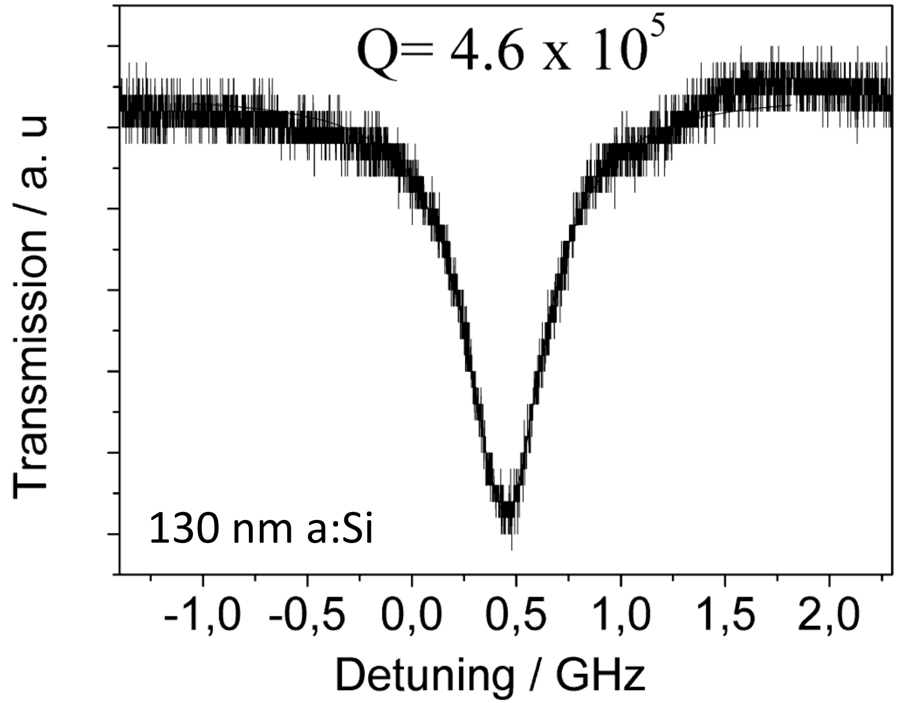
There is an analogy between a coated microresonator

D. Ristić, A. Chiappini, M. Mazzola, D.Farnesi, G. Nunzi-Conti, G.C.Righini, P.Feron, G.Cibiel, M.Ferrari and M.Ivanda, Whispering gallery mode profiles in a coated microsphere, Eur.Phys.J.SpecialTopics, 223, 1959–1969(2014)

Coating with silicon can increase the sensing sensitivity but will also reduce the Q-factor

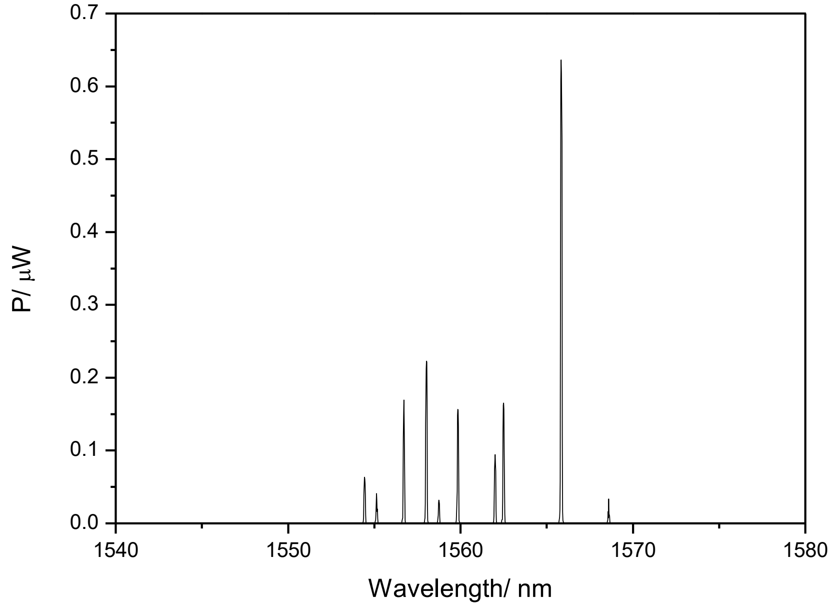
A coating method is needed which will not significantly reduce the Q-factor

Mechanisms of the reduction of the Q-factor: absorption, surface scattering



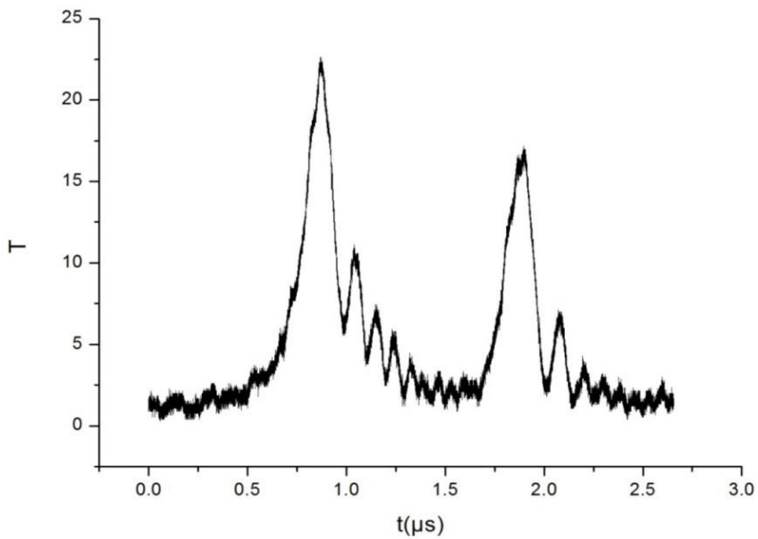
The LPCVD methods gives films with good surface quality

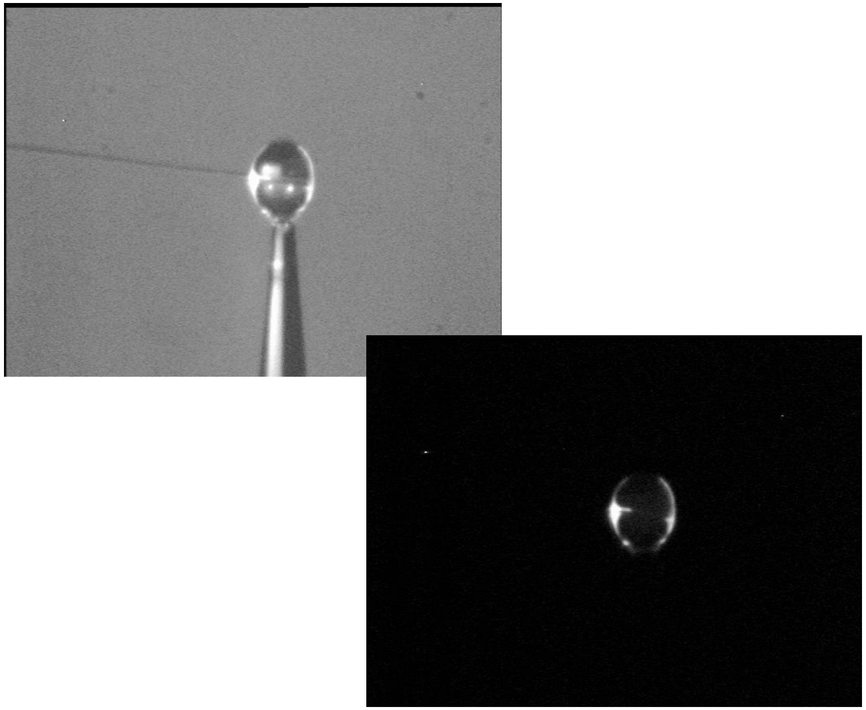
Application: lasing and wavelength selective amplification



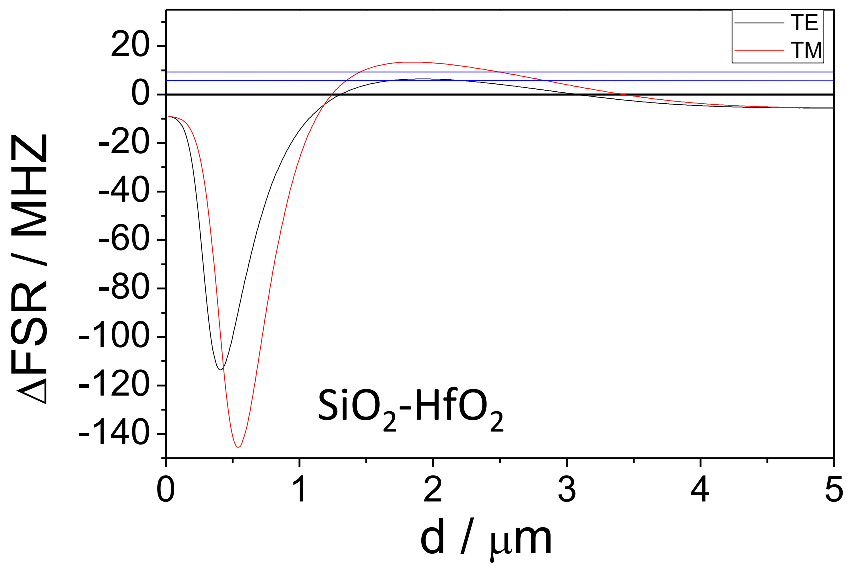
Er^{3+} ions are pumped at 1480 nm
Lasing occurs at wavelengths 1550-1570 nm

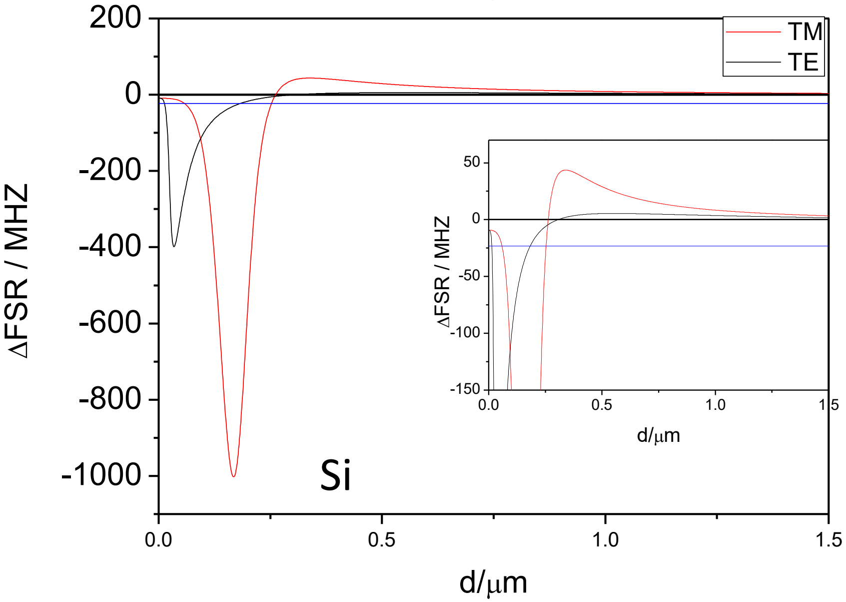
With the SiO2-HfO2 coating the max lasing power does not change on the scale of months





Application: Modal dispersion tailoring

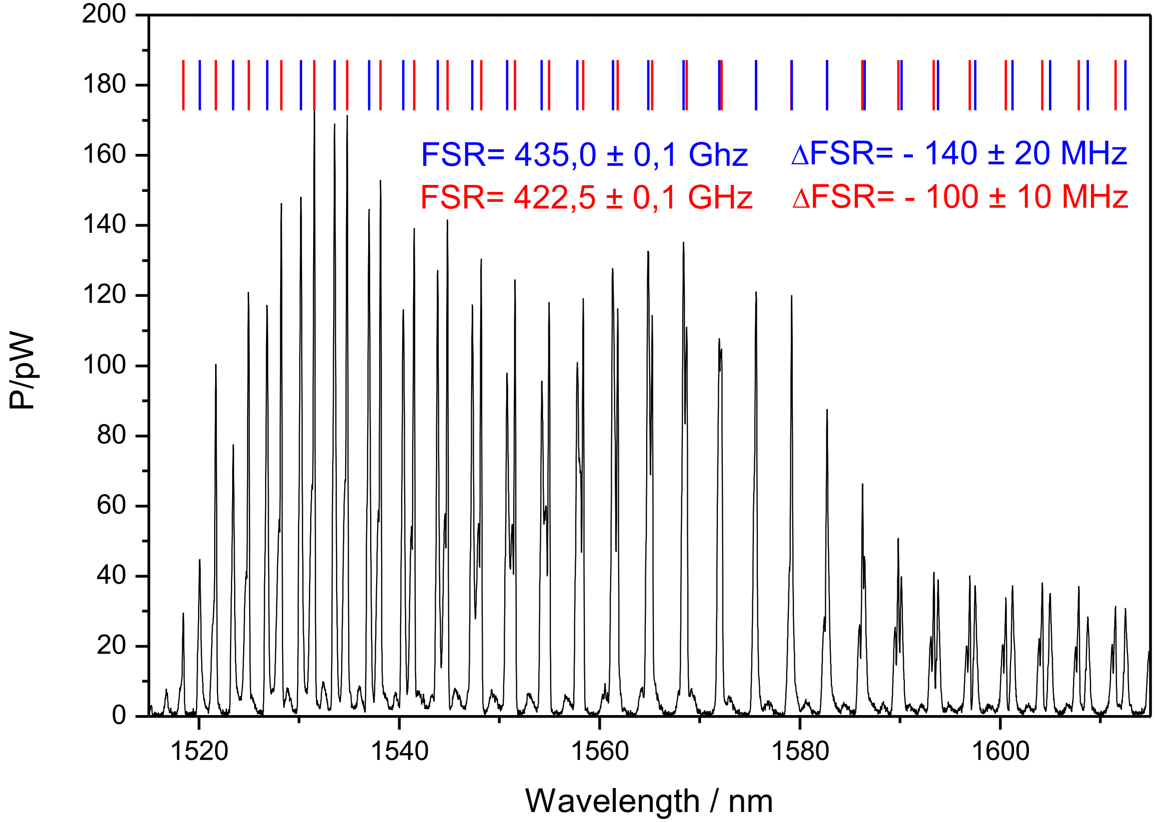


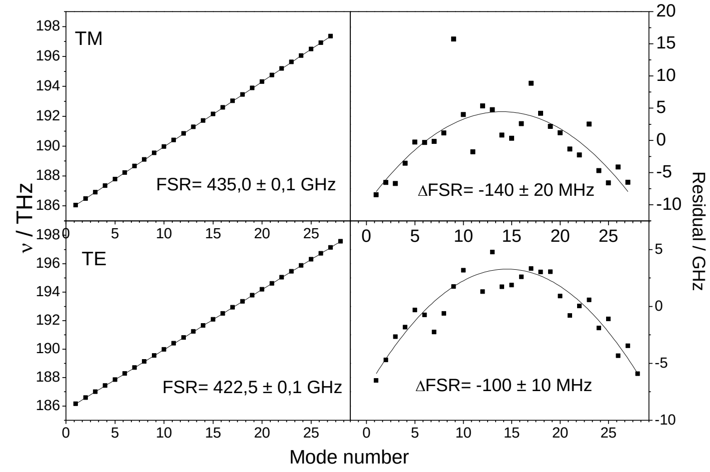


Modal distribution is a sum of a geometrical cavity dispersion and a material disperison

The geometrical cavity dispersion can be tailored by coating

For non-linear optics applications the overall modal dispersion should be small and anomalous





We managed to measure the overall modal dispersion using Er^{3+} as a probe

The measured modal dispersion is in agreement with theoretical predictions

D. Ristić, M. Mazzola, A. Chiappini, A. Rasoloniaina, P. Féron, R. Ramponi, G. C. Righini, G. Cibiel, M. Ivanda, and M. Ferrari, Tailoring of the free spectral range and geometrical cavity dispersion of a microsphere by a coating layer, Optics Letters, 39, 5173–5176 (2014).

Acknowledgments

✓ *Ruđer Boškovic Institute*, Zagreb, Croatia
✓ *CNR-IFN – Istituto di Fotonica e Nanotecnologia*
✓ *Facoltà di Scienze - Dipartimento di Fisica Univ. Trento*
✓ *FBK- Center for Materials and Microsystems*
✓ *IFAC-CNR*, Istituto di Fisica Applicata Nello Carrara, Firenze
✓ *Politecnico Bari, Dip. Elettrotecnica ed Elettronica*
✓ *Faculty of Mathematics and Physics*, Charles University in Prague
✓ CNRS-LASIR *Laboratoire de Spectrochimie Infrarouge et Raman*, Lille, Francia
✓ *Département Chimie, Département Physique, IUT Le Mans,*
✓ *Ecole Nationale Supérieure des Sciences Appliquées et de Technologies*, Lannion France
✓ *Lab. des Fluorures CNRS Université du Maine*, France, Le Mans
✓ *Centre National d'Etudes Spatiales (CNES), Toulouse, France*

NSBMO research project (2010-2013) of the Provincia Autonoma di Trento

CNES R&T project SHYRO (2011-2014)

Croatian Science Foundation Project No. IP-2014-09-7046.

COST MP1401