MICROCAVITY-BASED OPTICAL CHEMICAL SENSOR

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OUTLINE

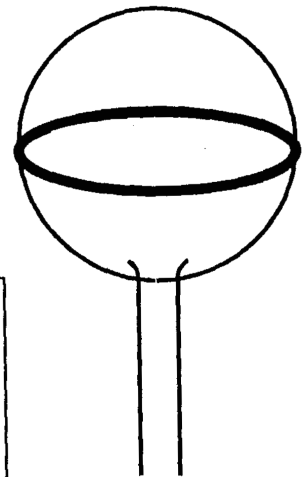
- The Whispering Gallery Mode Optical Microresonator - What is it
- Sensing modalities
- Preliminary experimental results with sensing in liquids
- Challenges
- Future directions

MICROSPHERE - A LOW-LOSS OPTICAL MICROCAVITY

Whispering-gallery modes - closed circular waves under total internal reflection (term by J.W.S.Rayleigh describing acoustic modes in the gallery of St.Paul Cathedral)

Sustained in any axisymmetric dielectric body with $R \geq \lambda$

- low material loss (transparent material, e.g fiber grade silica)
- low bending loss ($R >> \lambda$)
- low scattering loss
  (TIR always under grazing incidence + molecular-size surface roughness)



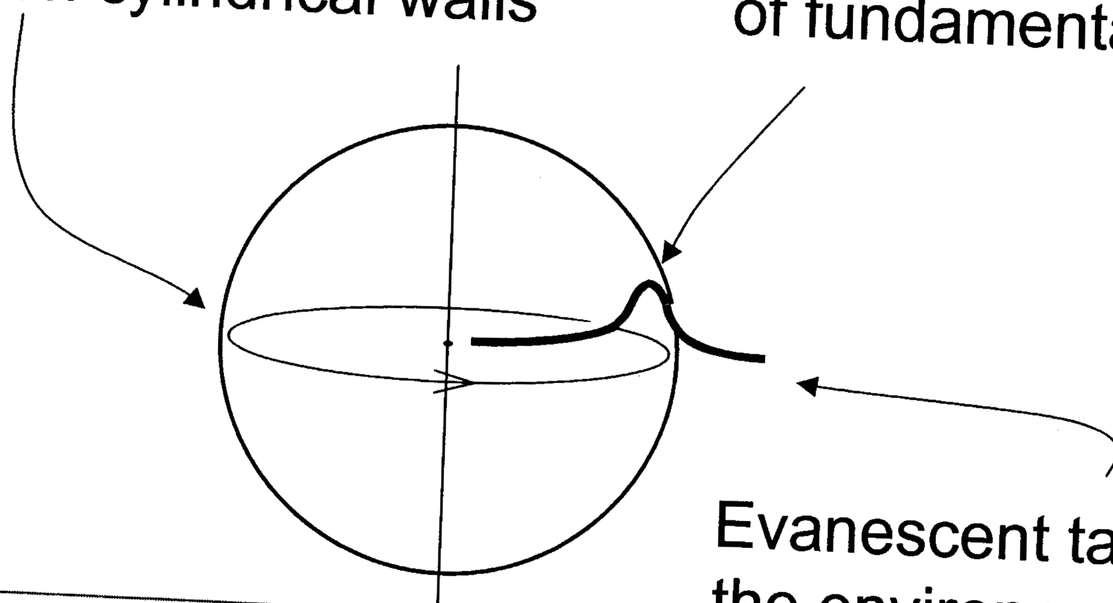
Visualization of WG mode field by residual scattering in silica microsphere, *V.S.Ilchenko et al, Opt.Commun. 113, p.133(1994)*

Quality-factor $Q = \lambda/\Delta\lambda_{RES}$	-	up to $\sim 10^{10}$
Photon lifetime $\tau = \lambda Q/2\pi c$	-	up to $\sim 3\mu s$
(cavity ringdown time)		
visible and near-infrared band:		*Opt.Lett. 21, p.453 (1996)*
		Opt.Lett. 23, p.247 (1998)

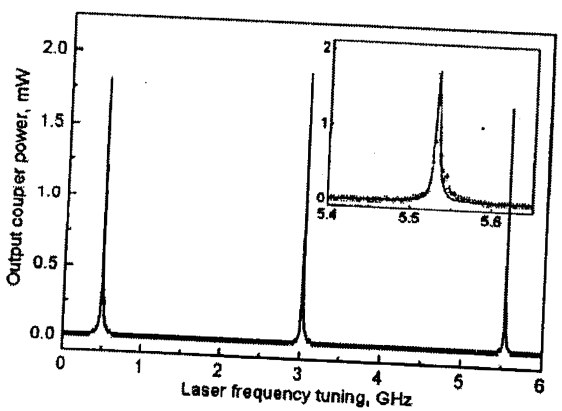
MICROCAVITY ANATOMY

Curved surface confines light in the equatorial plane – better than cylindrical walls

Radial intensity distribution of fundamental mode



Evanescent tail probes the environment



Example of sphere transmission spectrum

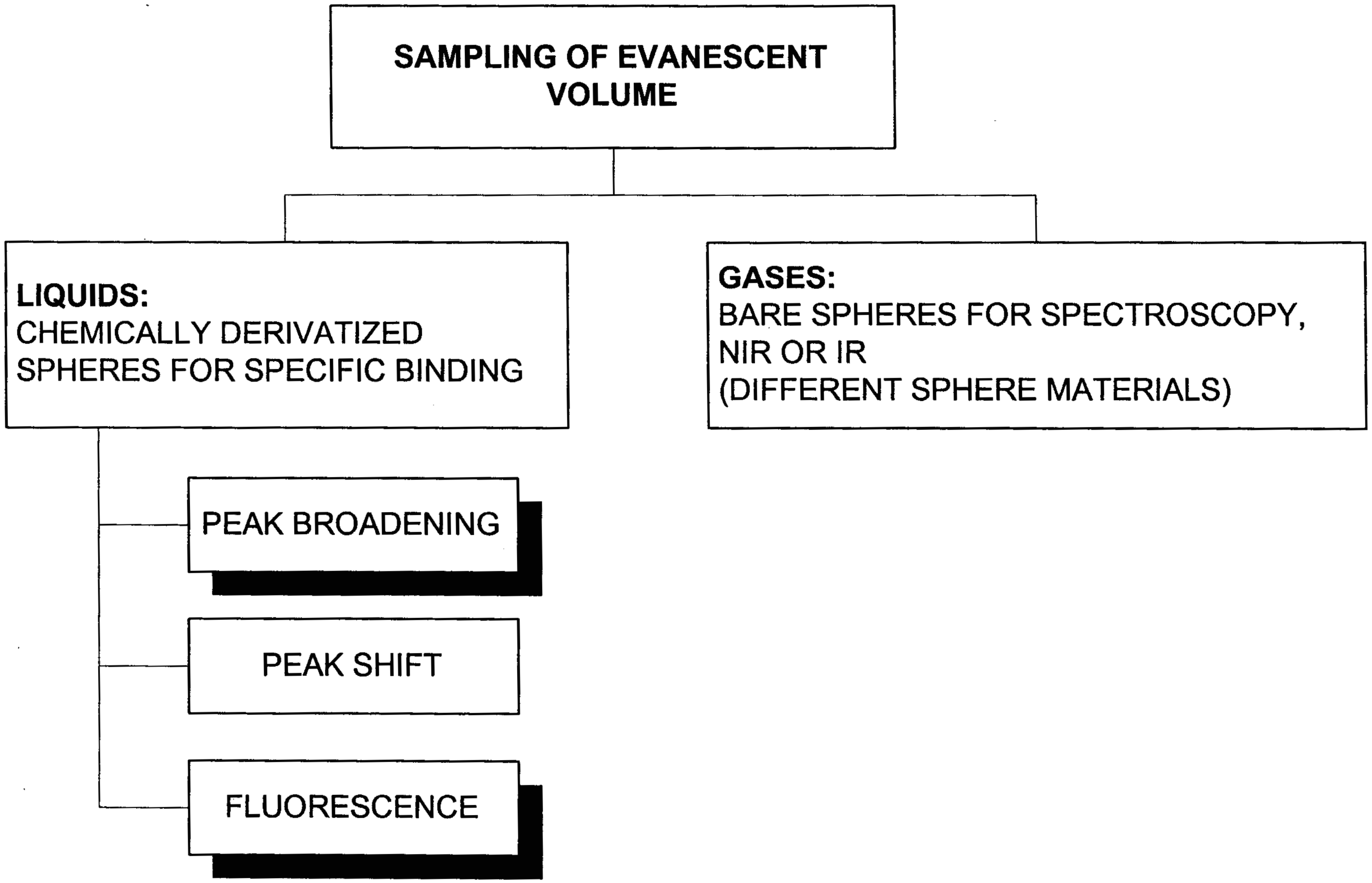
LABORATORY SETUP

WHY MICROCAVITIES ARE IMPORTANT AS AN *IN-SITU* SENSOR PLATFORM

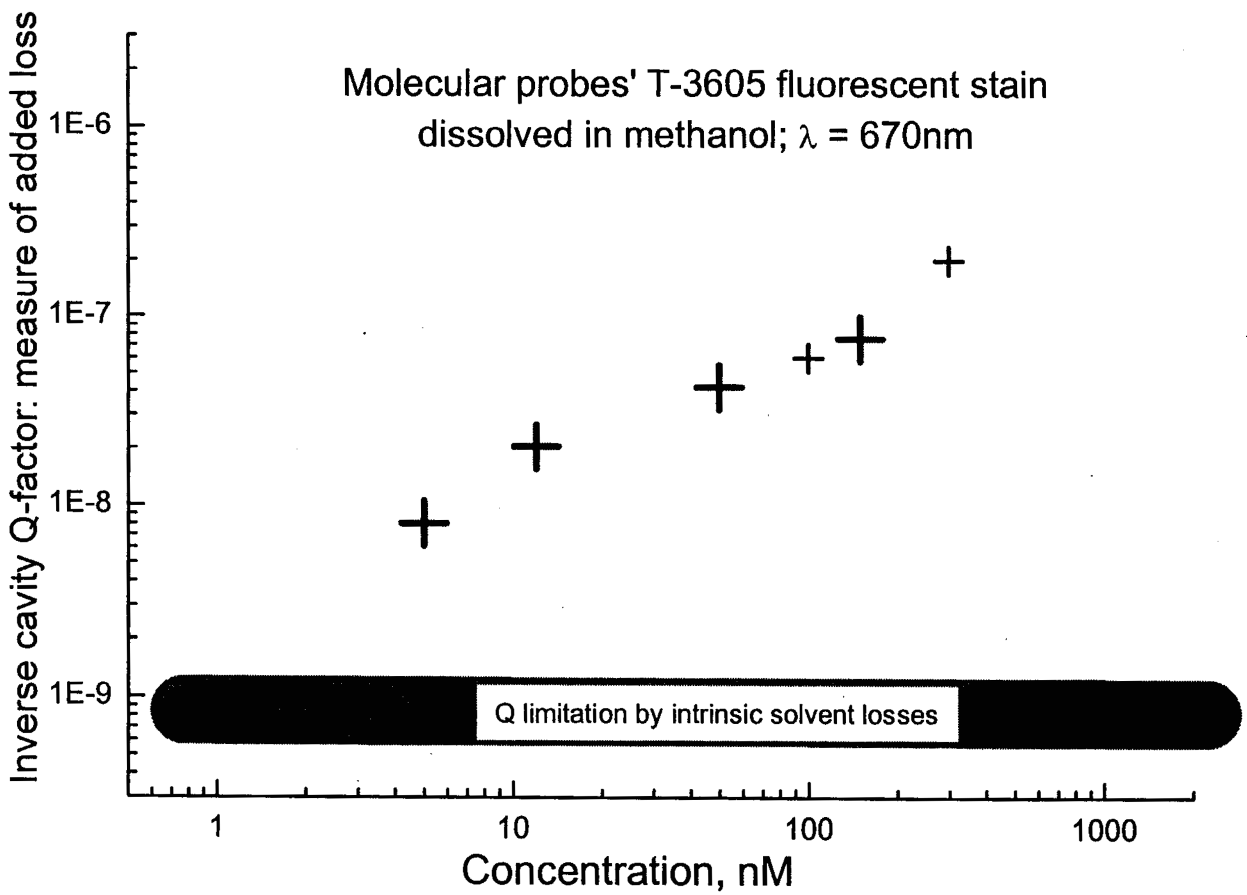
- High Q allows for sensitive detection
- High sensing pathlength to size ratio lends itself to system miniaturization
- Ability to use at any optical wavelength – multiple sensing modalities are enabled
- Ability to use in multiple/integrated configurations
- Ease of sampling with simple fiber coupling

SENSING MODALITIES

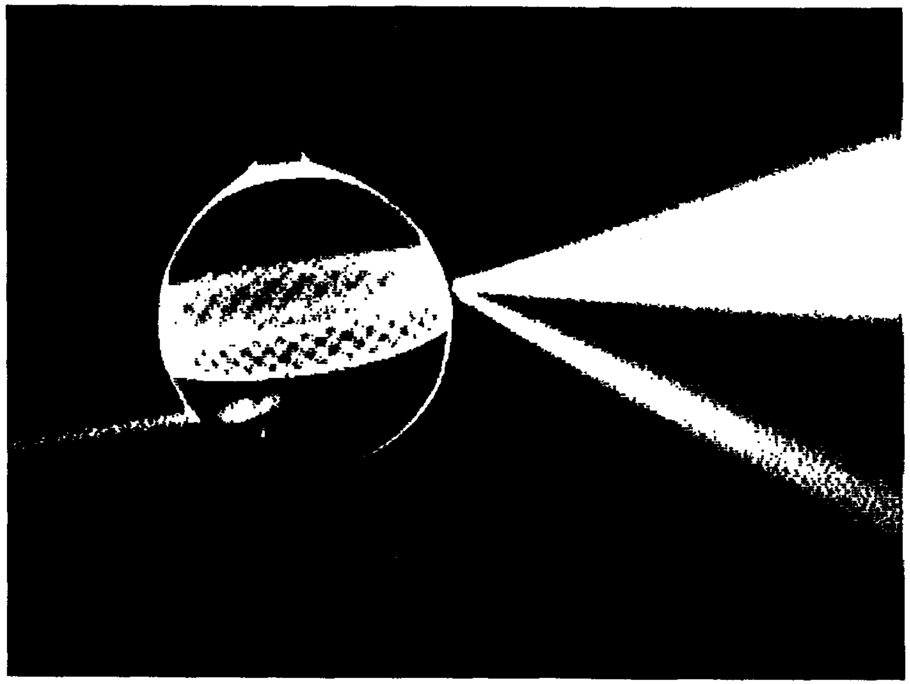
Tens of meters of effective pathlength collapsed into a sub-millimeter sized cavity



QUALITY FACTOR DEGRADATION DUE TO FLUORESCENT DYE IN SOLUTION

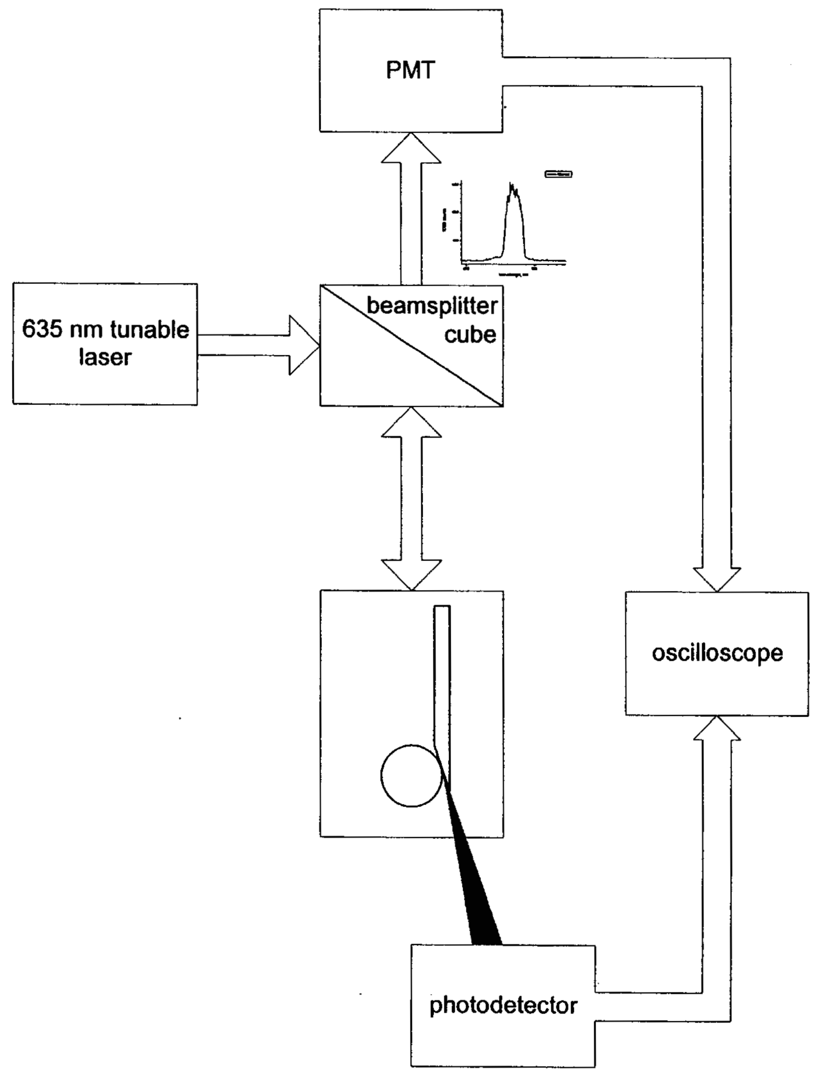


FLUORESCENT VISUALIZATION OF WHISPERING GALLERY MODES



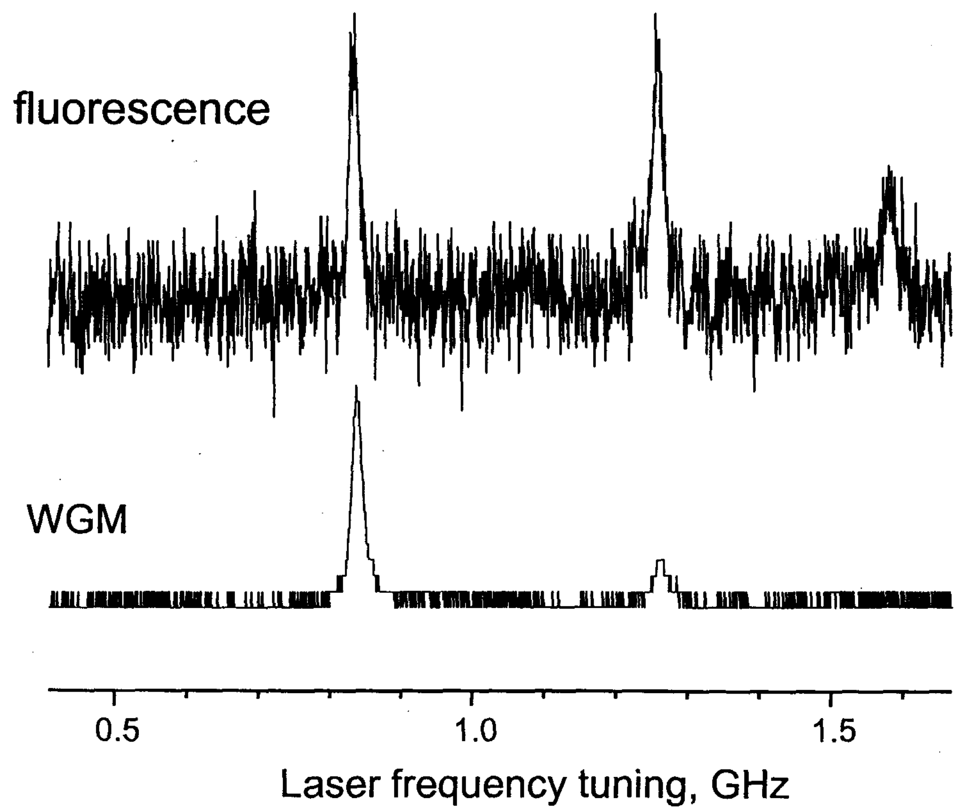
Microsphere immersed into a 100 nM solution of TO-PRO5 dye from Molecular Probes, observed through emission filter.

FLUORESCENCE COLLECTION THROUGH COUPLER: SETUP



FLUORESCENCE COLLECTION THROUGH COUPLER: DATA

0.1 nM TO-PRO3 in MeOH
average 16 spectra
FWHM ~17MHz, Q=2.9x10^7



PATHWAY TO SPECIFIC DETECTION IN LIQUIDS

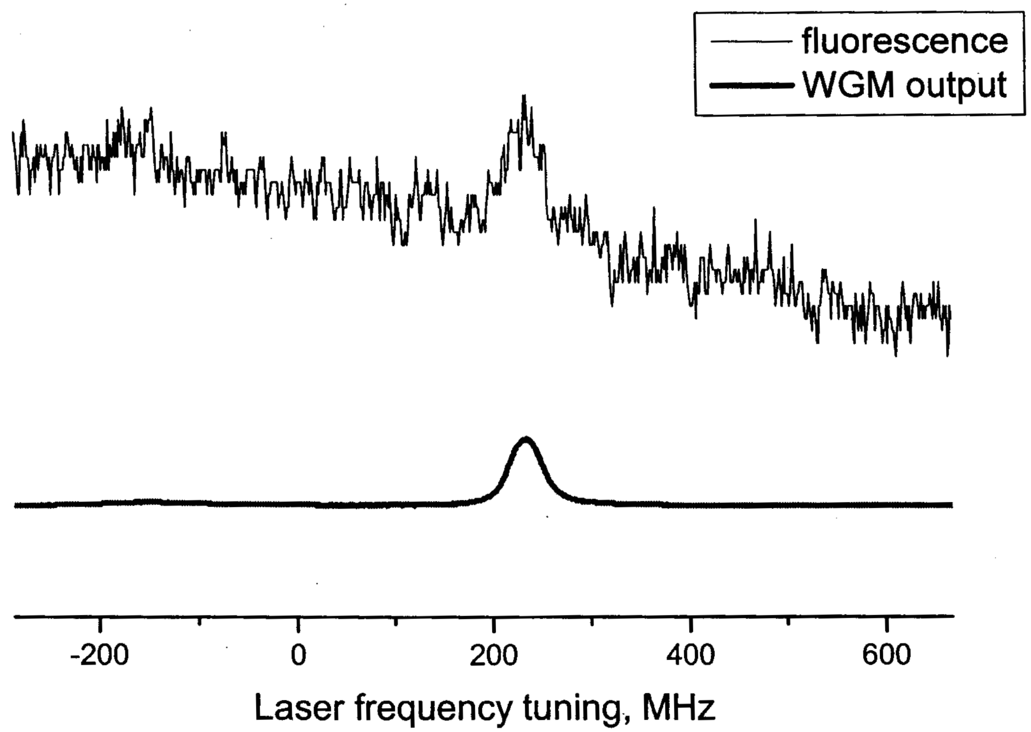
Typical approach:
- Derivatize sensor surface with capture molecules (antibodies, single strand DNA etc.)
- Expose sensor to solution containing target molecules
- Detect binding

Challenges (multiplied by Q☺):
- Preserving smooth surface after chemical processing
- Discriminating against non-specific binding
- Controlling the temperature (if peak shifting is observed)

SURFACE CHEMISTRY IS CRUCIAL FOR SENSOR OPERATION

Streptavidin linked to sphere surface, AFM, 10x10 micron scan. Surface scattering reduces Q down to 10^5 or less.

FLUORESCENT DETECTION OF SPECIFIC BINDING

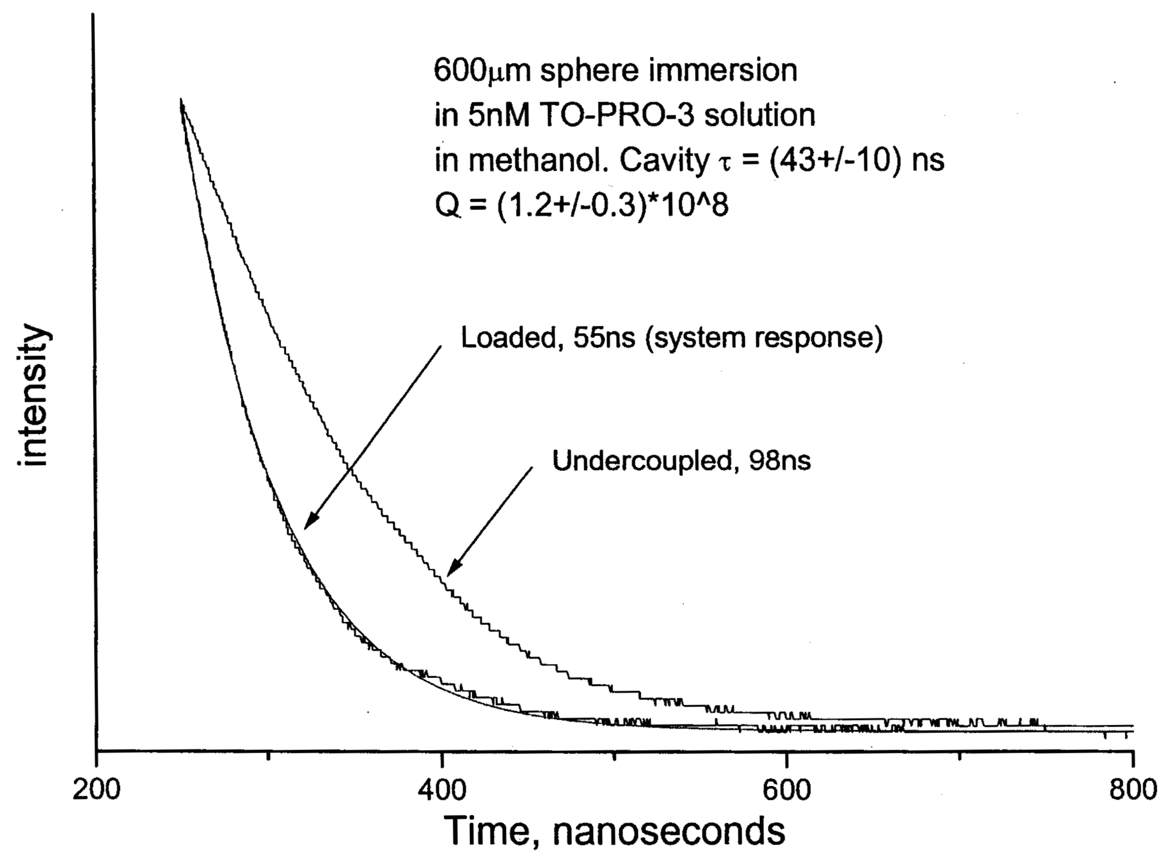


Sphere is coated with BSA-biotin and exposed to streptavidin conjugated with a fluorescent probe, 1μg/ml.

FUTURE DIRECTIONS

- Improve surface chemistry procedures to preserve high Q.
- Enhance dynamic range of fluorescence detection.
- Demonstrate detection of specific binding with antibody capturing.

Extra slides



Cavity ringdown measurement of microsphere cavity Q.
Q=1.2 x 10^8 vs 1.1 x 10^8 from linewidth measurement