

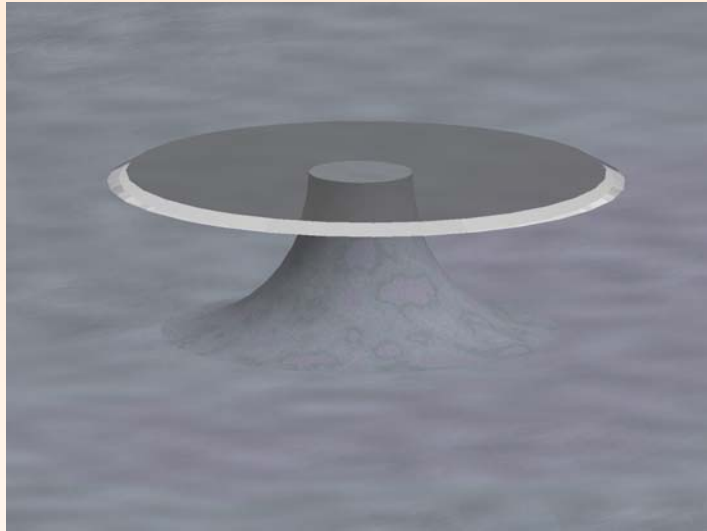
# Micromolding Of High-Q Toroid Resonators

**A. Martin, L. Yang, D. Armani, K. Vahala**  
*California Institute of Technology*

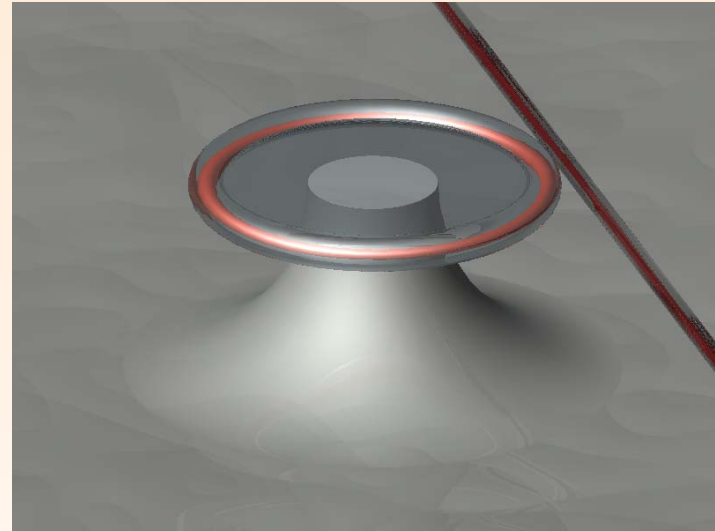
LEOS October 2003



# Silica Microresonator Devices



**Silica High-Q  
Microdisk**  
 $Q < 10^6$



**Silica Ultra-High-Q  
Microtoroid**  
 $Q > 10^8$

**Quality Factor: Q**

$$\frac{1}{Q_o} = \frac{1}{Q_{\text{scat}}} + \frac{1}{Q_{\text{mat}}}$$

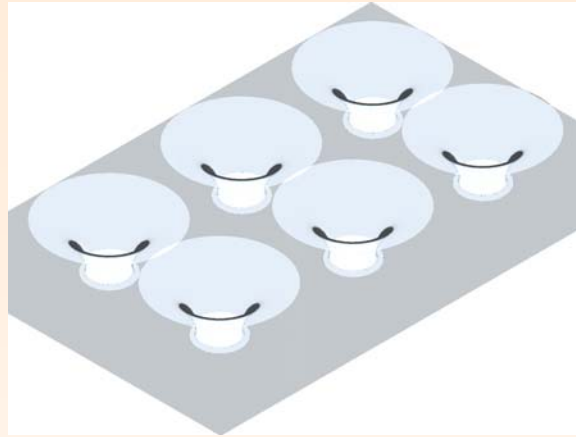
$Q_{\text{scat}} \sim$  Surface Scattering  
 $Q_{\text{mat}} \sim$  Material Loss

# Replica Molding of Microresonators



## Perfect Master

- Silica UHQ Microtoroid



## Negative Mold

- PDMS Flexible Mold  
(*Polydimethylsiloxane*)



## Polymer Microtoroid

- Non-Shrinking
- Low Optical Loss

- Absorption-limited polymer microtoroids

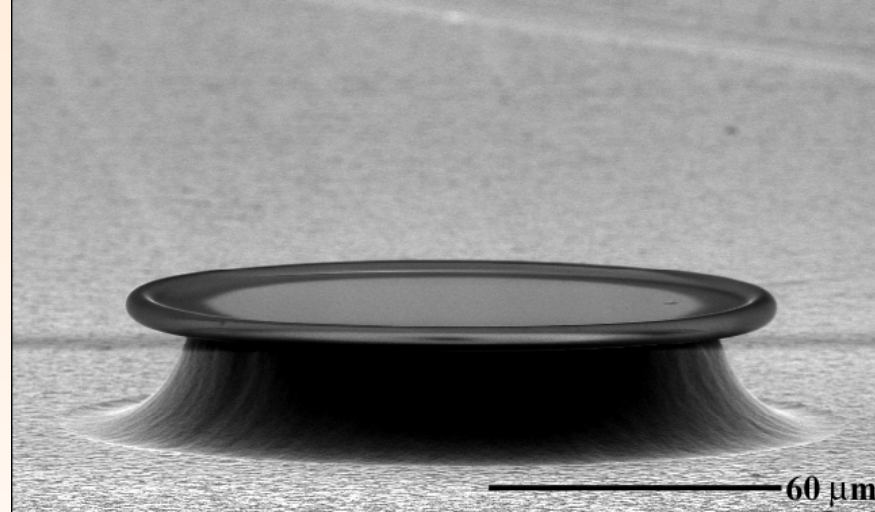
$$\frac{1}{Q_o} = \frac{1}{Q_{\text{mat}}}$$

- Probe optical loss of novel polymers

# Replica Molding: Perfect Masters

## Perfect Master

- Smooth surface reduces scattering



SEM of Ultra-High Q microtoroid

## Preparing the master and mold fabrication

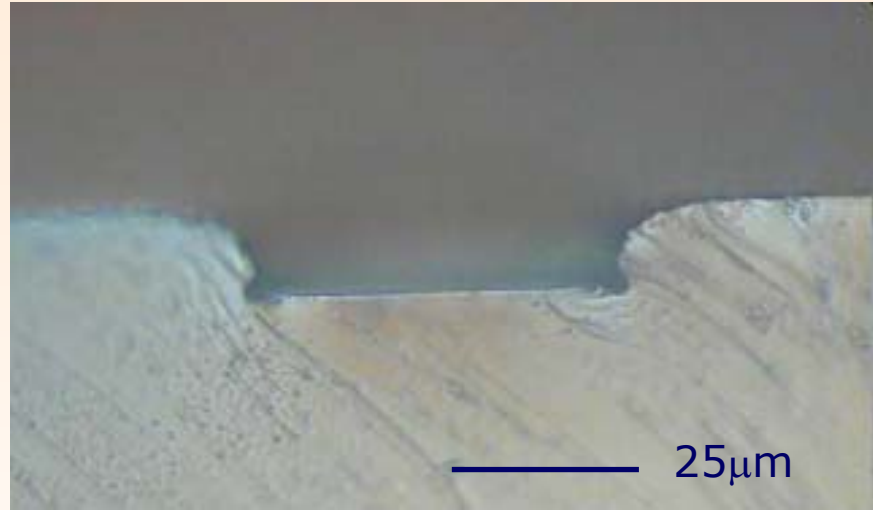
- Silanate the silica surface
- Coat master with PDMS



# Replica Molding: Flexible Mold

## PDMS Mold

- Replicates overhang and smooth toroid



Cross section of PDMS mold

## Preparing the mold and polymer disk fabrication

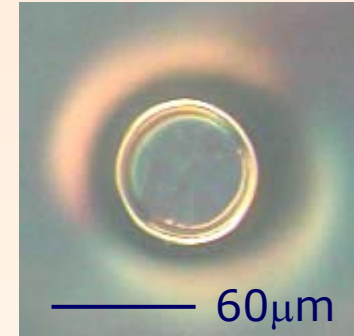
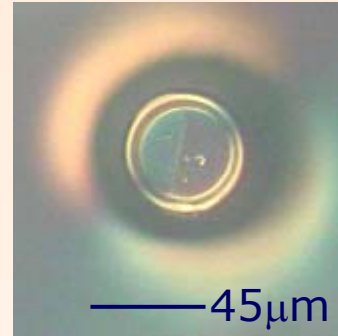
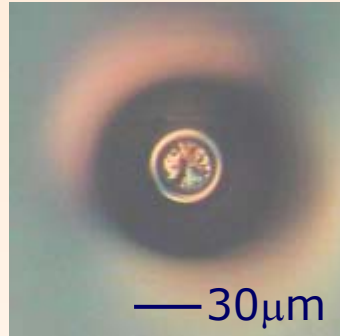
- Expose the mold to an O<sub>2</sub> plasma
- Pour polymer into the mold



# Replica Molding: Polymer Microtoroids

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## PDMS Microtoroids

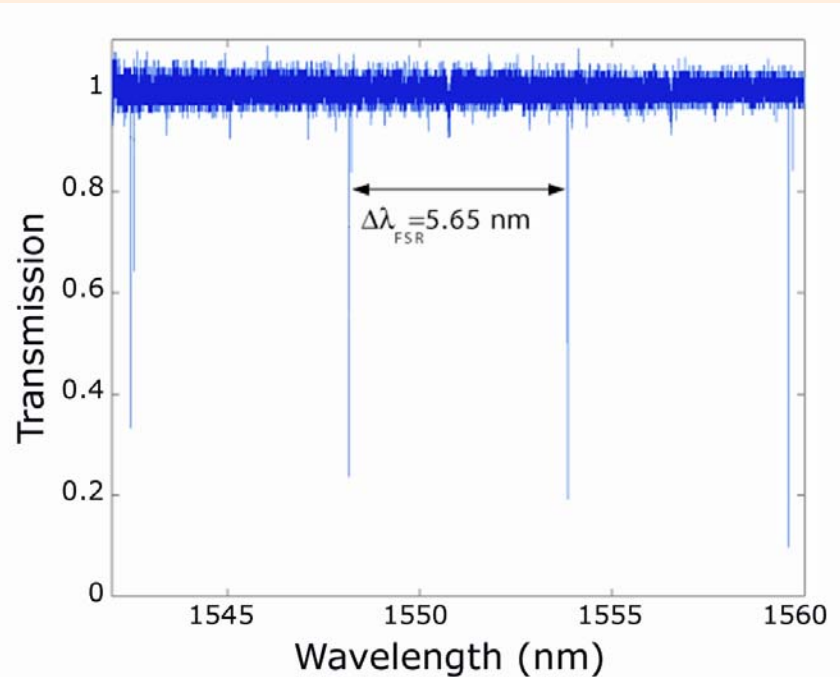


## PDMS Characteristics

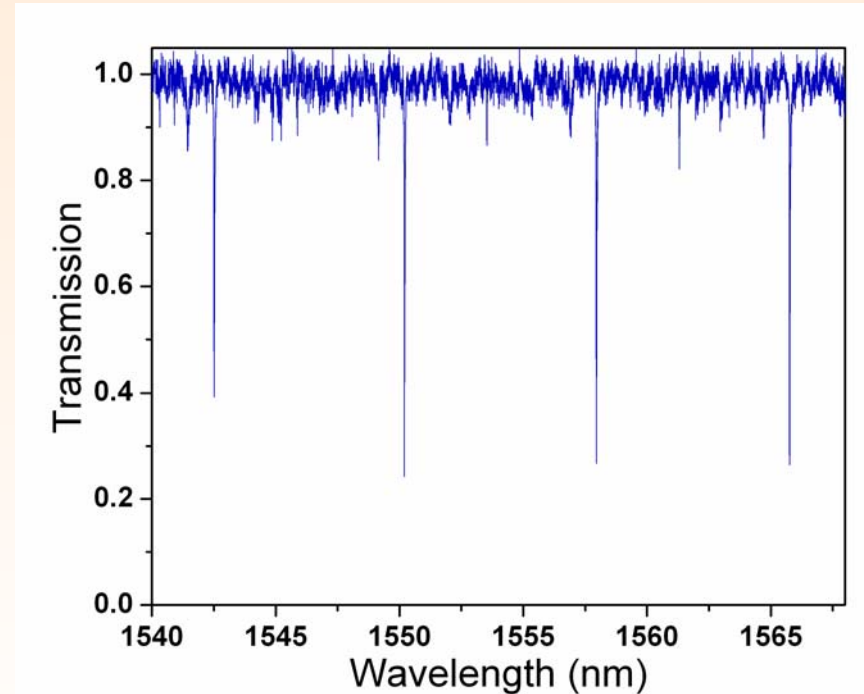
- Optical structures (waveguides) previously fabricated
- Optical absorption spectra obtainable from manufacturer

# Comparison of Master and Polymer Toroids

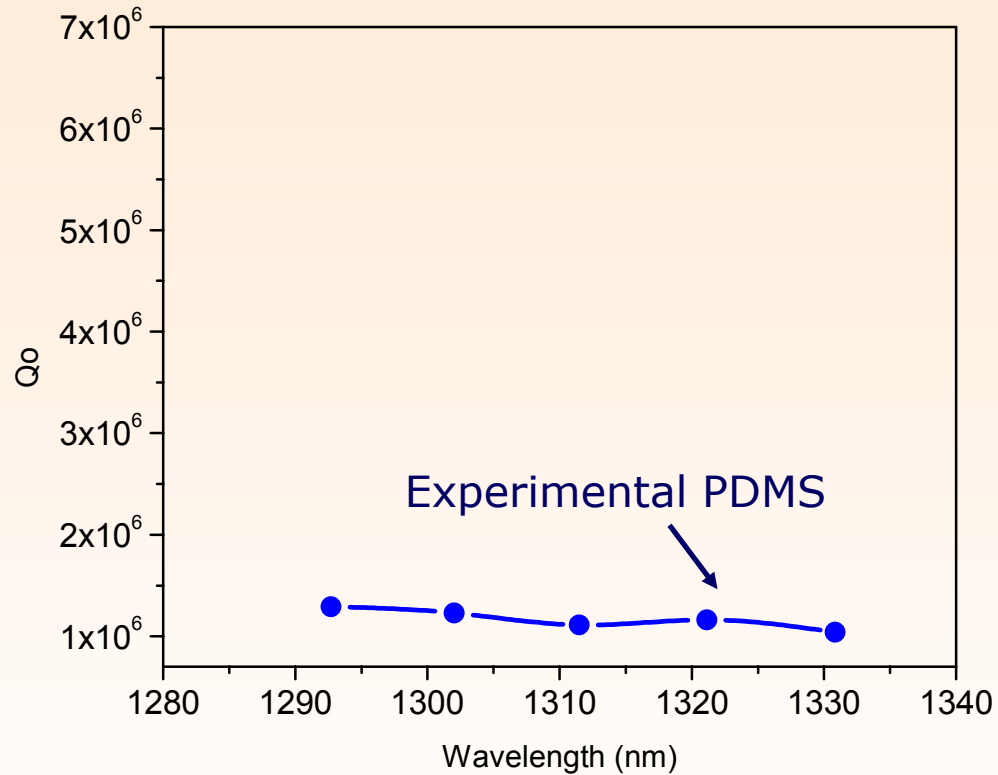
## Silica Ultra High Q Microtoroid Broad Band Spectra



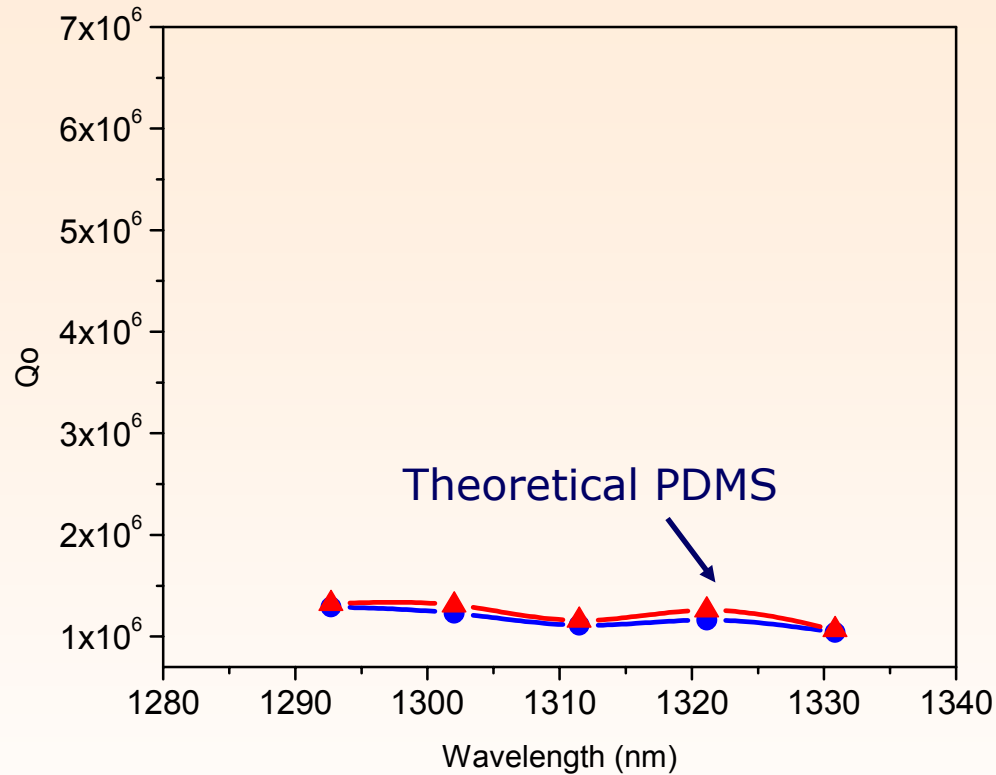
## Polymer High Q Microtoroid Broad Band Spectra



# Experiment and Theory Comparison

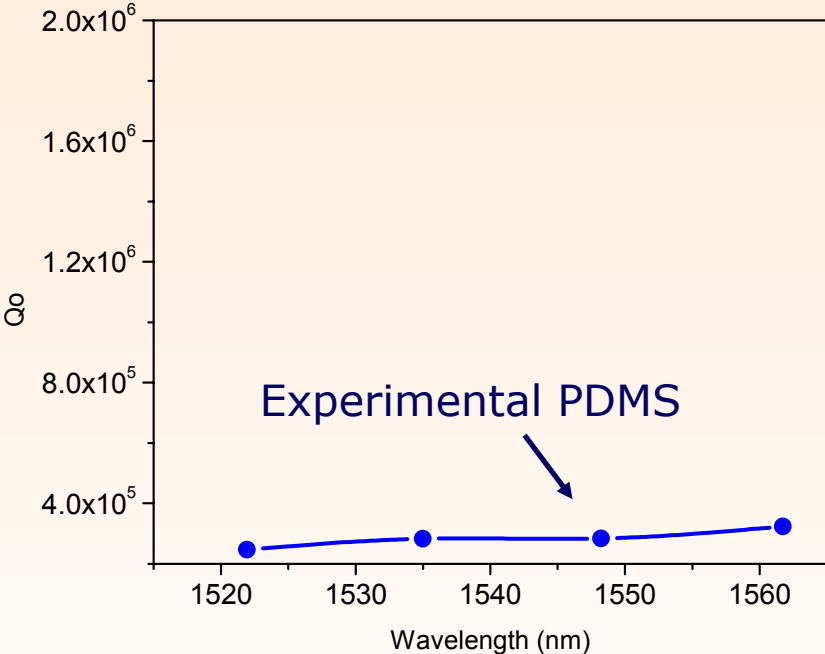
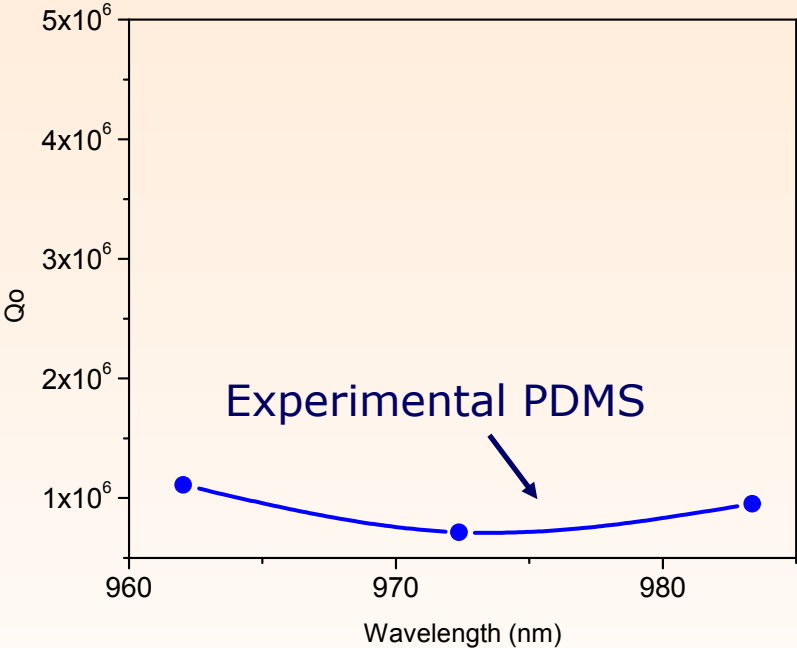


# Experiment and Theory Comparison

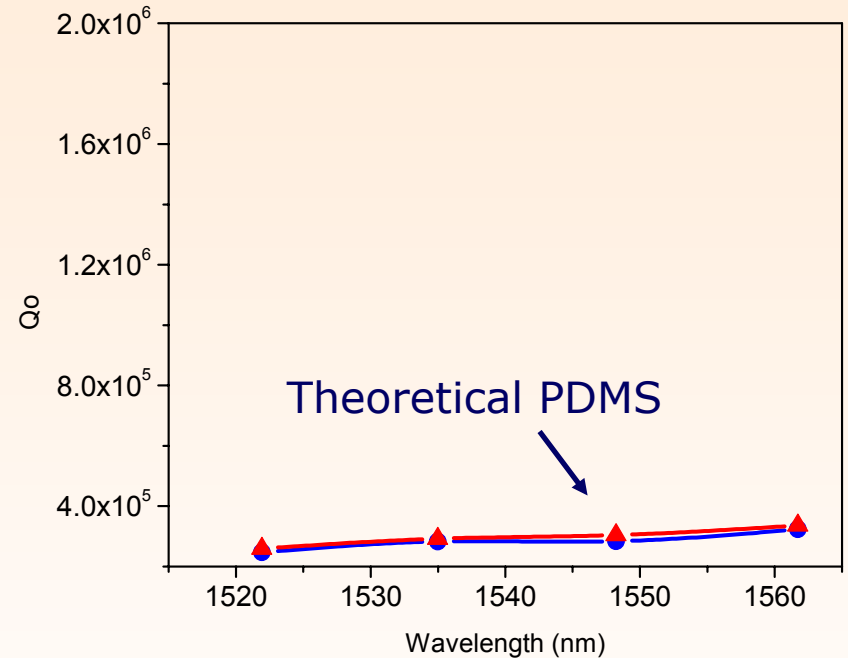
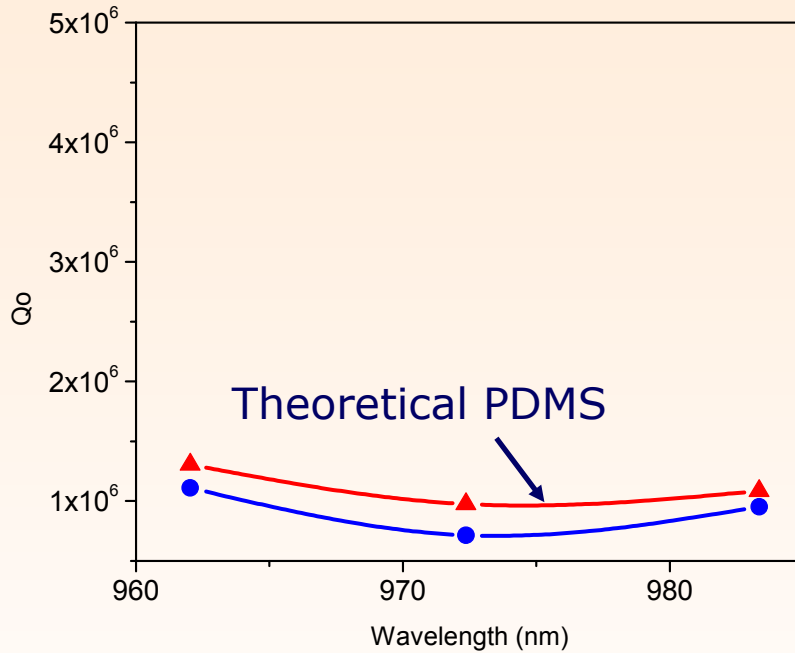


**Nearly absorption-limited polymer microresonator**

# Quality Factor at other Wavelengths



# Quality Factor at other Wavelengths

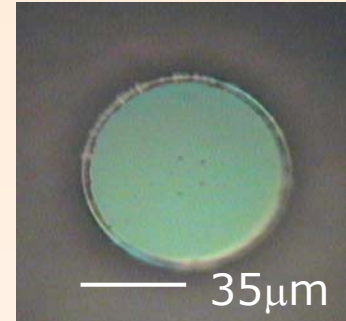
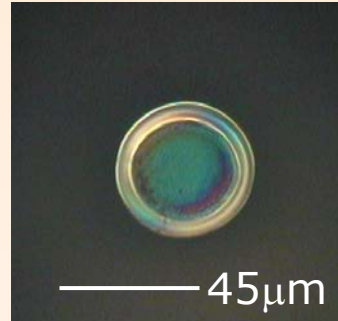
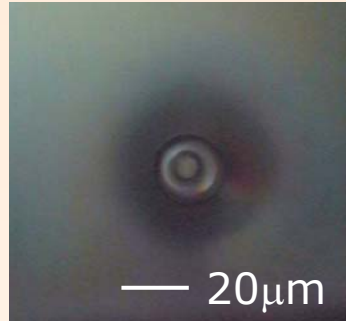


**Quality factor is limited by material loss, not surface scattering**

# Vicast® as an Optical Polymer

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## Vicast® Microtoroids

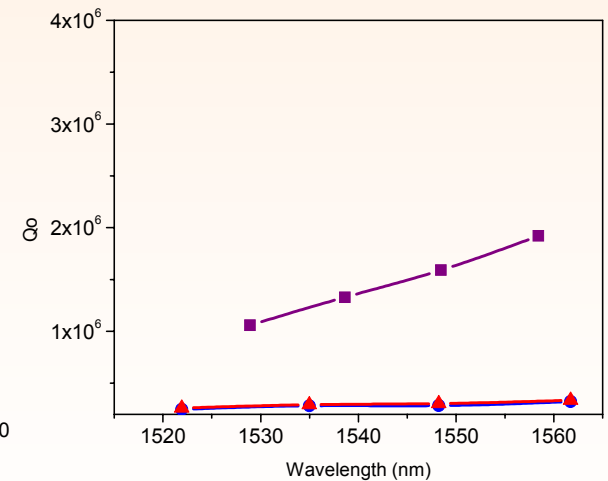
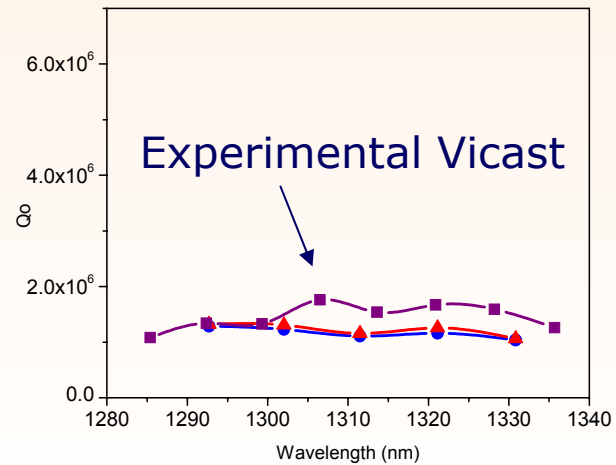
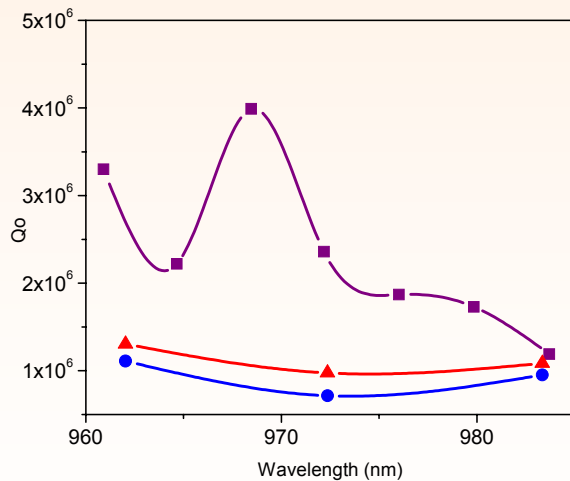
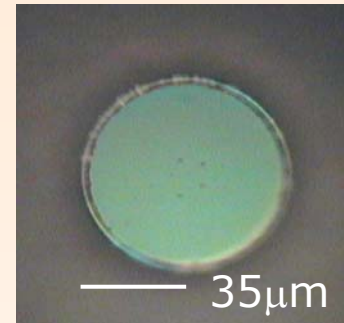
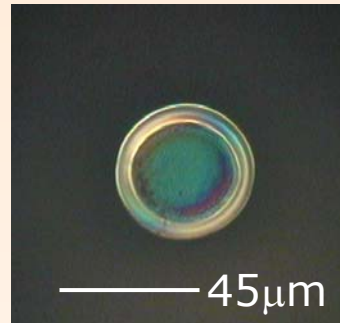
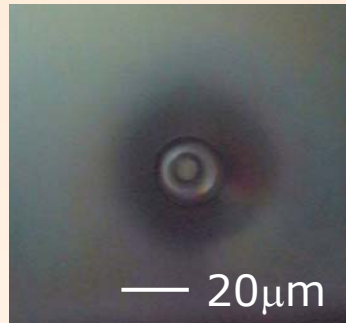


## Vicast® Characteristics

- Commercial structures previously fabricated
- No absorption spectra obtainable

# Vicast® as an Optical Polymer

## Vicast® Microtoroids



**40x improvement in Q over previous polymer microresonators**

# In Summary

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- Fabricated planar arrays of single mode High-Q polymer microtoroids
- Demonstrated faithful replicas of an ideal microresonator master
- Used Vicast® to fabricate polymer High-Q microtoroids with 40x improvement in Q factor
- Possible improvement in Q factor with lower loss polymers (PMMA)
- Fast, accurate method to determine optical loss in previously unexplored polymers

Presentation is available at:

**[www.its.caltech.edu/~vahalagr](http://www.its.caltech.edu/~vahalagr)**