VNIVERSITAT DE VALÈNCIA

Nonlinear ultrafast fiber optic devices based on Carbon Nanotubes

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Outline

- Introduction
- CNT-coated TFBG
- Nanotube deposition
- Nonlinear experiment
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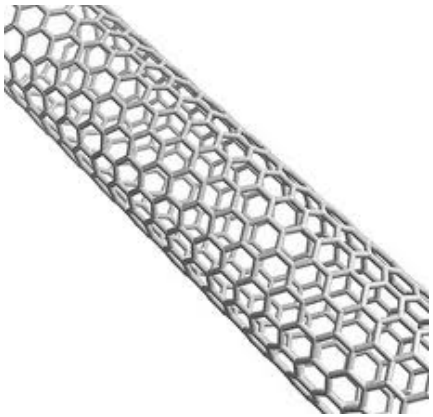
Introduction

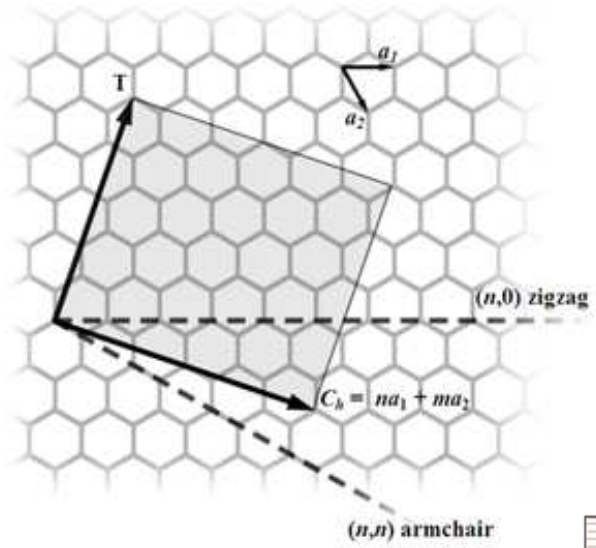
- Use of nonlinear materials for optical applications

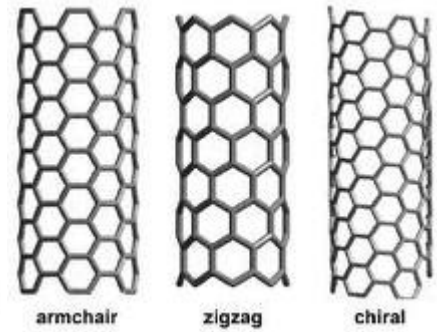
Second harmonic generation	Optical parametric amplification	Four wave mixing
Saturable absorbance	Wavelength conversion	...

- Ultrafast response, large bandwidth, high damage threshold, fiber compatibility

Carbon nanotubes



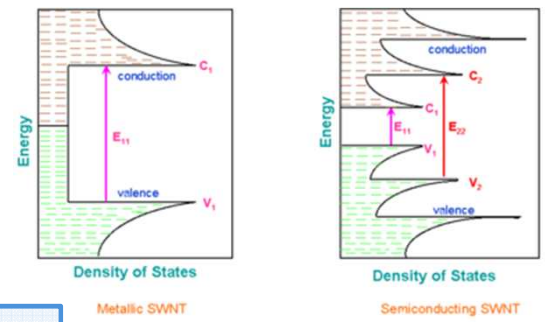




n=m ***m=0*** ***other***

$$d = \frac{a}{\pi}\sqrt{(n^2 + nm + m^2)}.$$

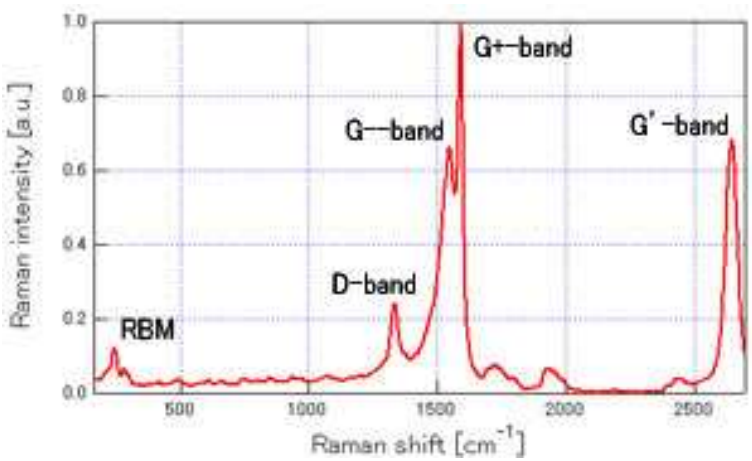
- Single Walled CNT
- Double Walled CNT
- Multiple Walled CNT

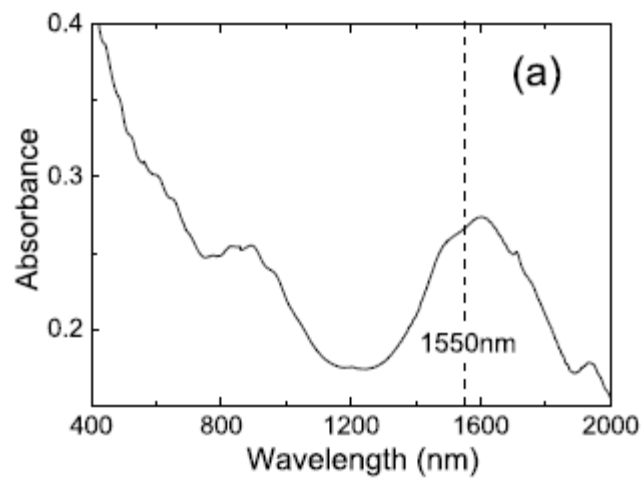


Diameter ~ few nm
length ~ hundreds µm ⇨ Unidimensional system

Introduction

- Interesting optical properties
- Depending on the chirality, CNTs can behave as conductor or semiconductor in optical frequencies
- The absorption band is related to the tube diameter

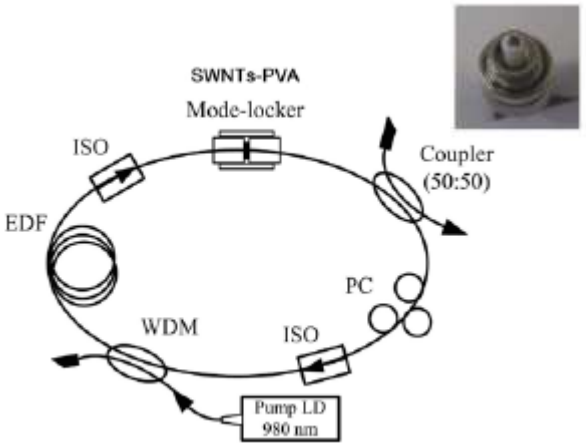




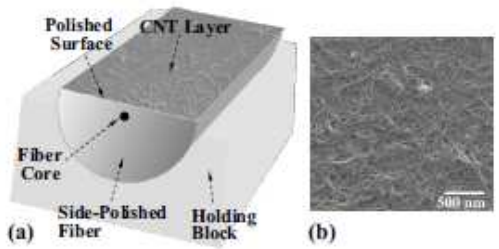
- This absorption is saturable

Introduction

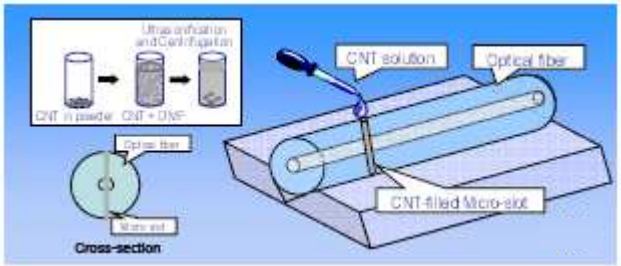
- CNT-based Mode-locked fiber lasers approaches



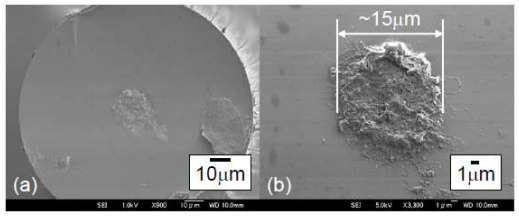
CNT composite polymers



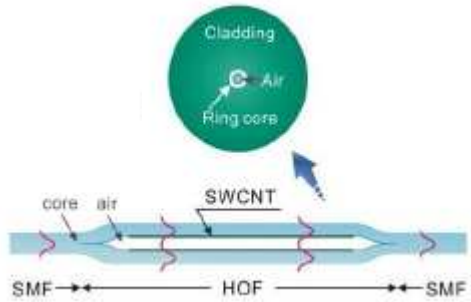
CNT deposited on D-shaped fiber



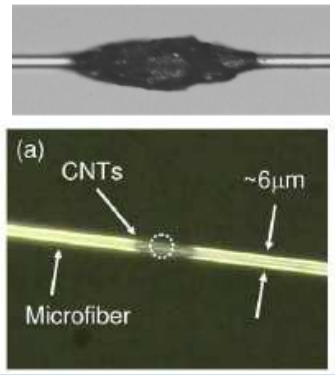
Fiber microchannel filled with CNT



Selective CNT deposition on fiber end



CNT deposition in hollow fiber



CNT deposition on tapered fiber

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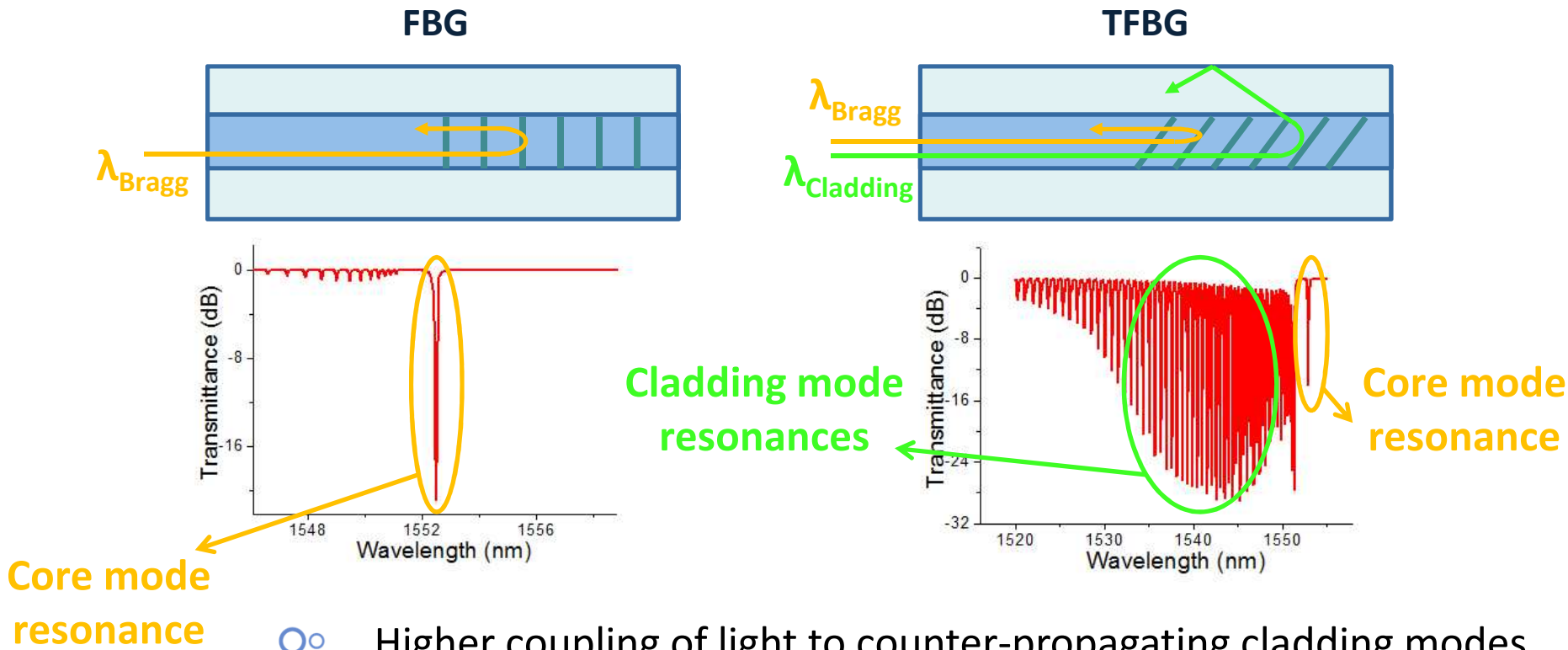
CNT-coated TFBG

- CNT for mode locked fiber lasers: Interest in all-fiber solutions
- Damage threshold of CNTs not high: distributed interaction desired
- Avoid delicate fiber structures

Use of tilted fiber Bragg grating (TFBG)

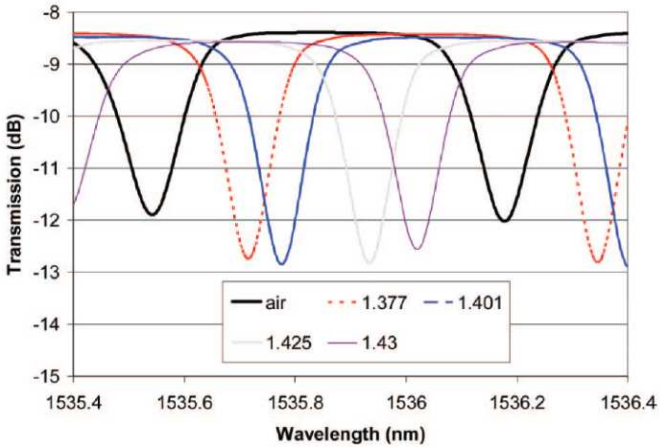
Tilted fiber Bragg Gratings



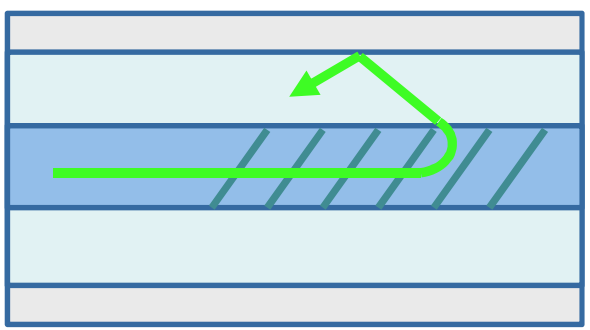
- Higher coupling of light to counter-propagating cladding modes
- Cladding mode resonance frequencies depend on, among other factors, the external refractive index n_{ext}

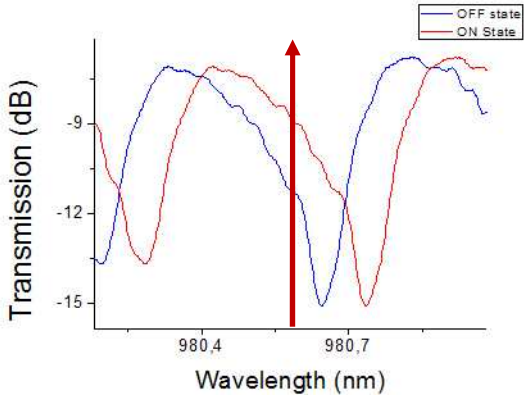
CNT-coated TFBG

- Light coupled to a cladding mode interacts with the outer medium
- Cladding mode resonance frequency shifts as n_{ext} varies
- Nonlinear external layer → $\mathbf{n_{ext}(I_{cladding})}$



CNT layer





Nonlinear transmittance response **T(I)**

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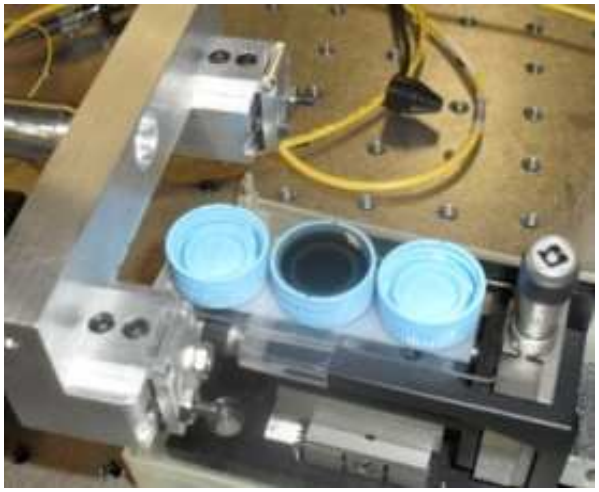
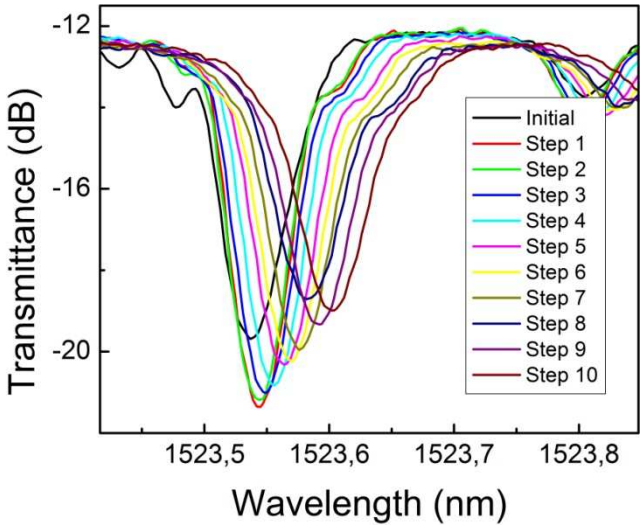
Nanotube deposition

1) Dipping method

- Fiber 3min immersion in 3-aminopropyltriethoxysilane (APTES) solution, COOH-SWNT/DMF dispersion and pure water sequentially
- 10 steps process → coating thickness progressive growth
- Measurements of optical transmittance each step

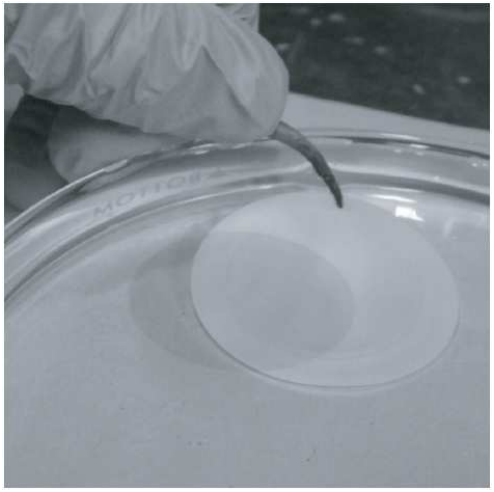


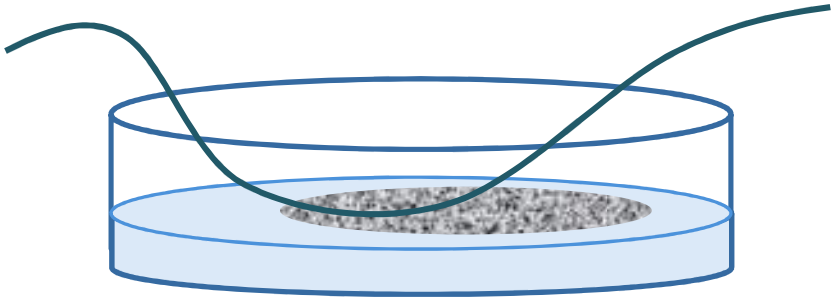


Nanotube deposition

2) Wrapping method

- Preparation of SWNT film floating in water:
  - CNT film implemented by vacuum filtration
  - Easy detachment from the filter membrane in water
- Manual wrapping of SWNT film on the fiber

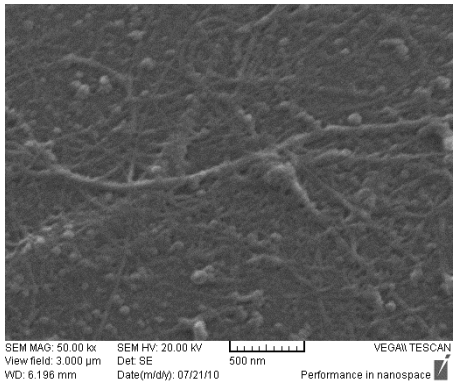


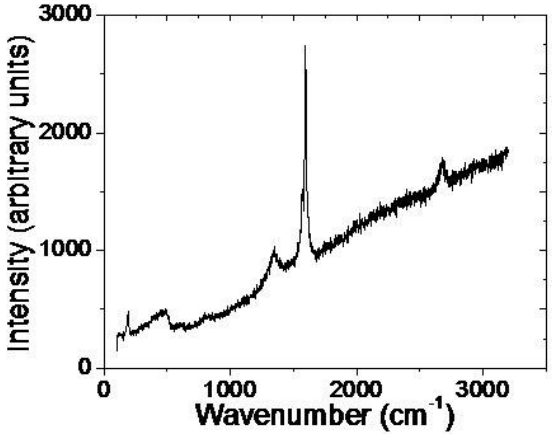


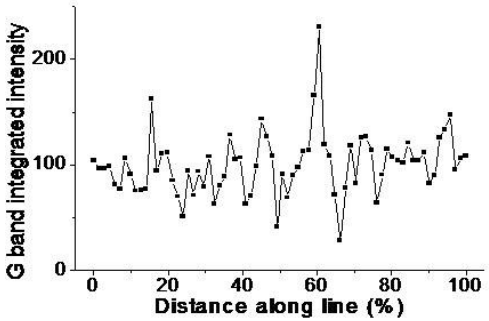
- Thicker coating compared to dipping method is obtained

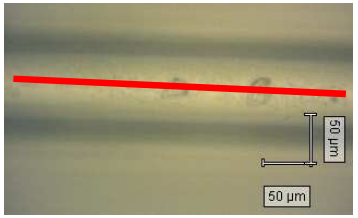
Nanotube deposition

Dipping

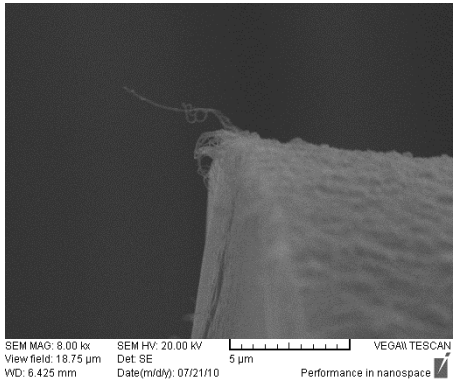


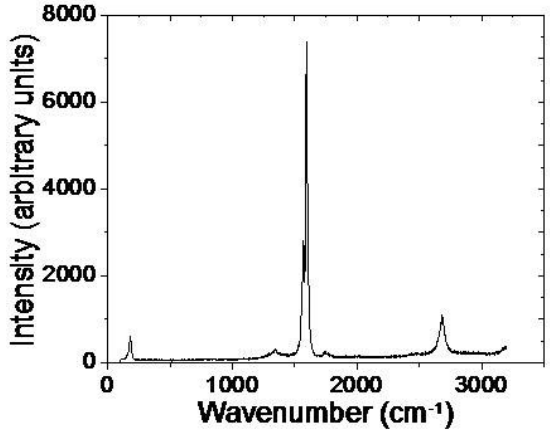


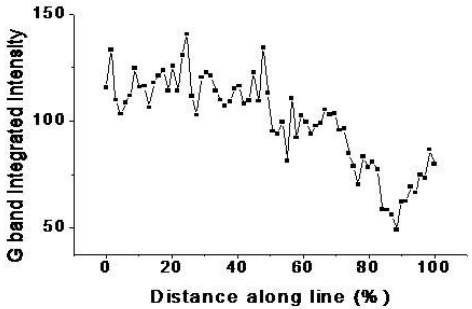




Wrapping







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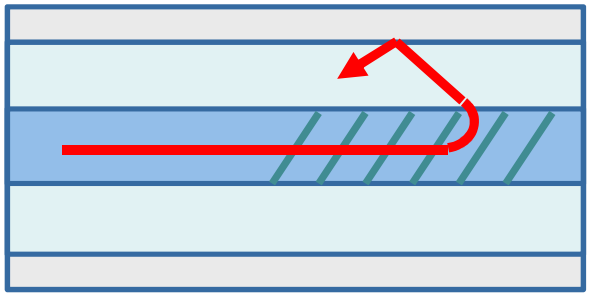
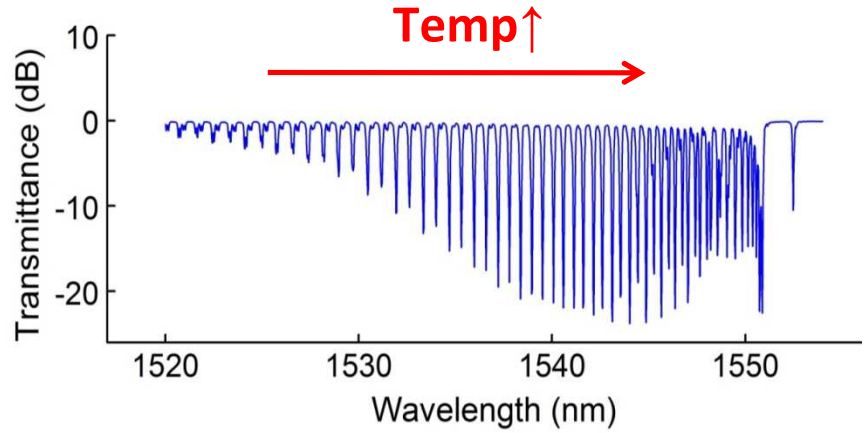
Nonlinear experiment

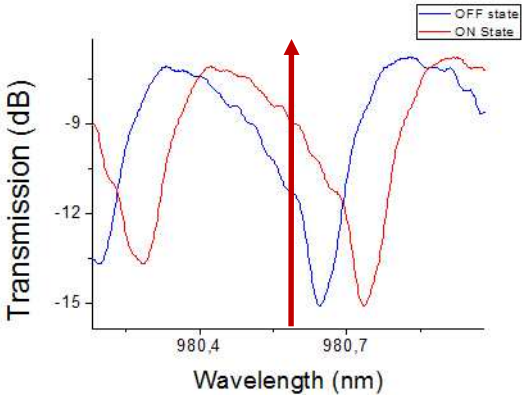
- TFBG response sensible to temperature





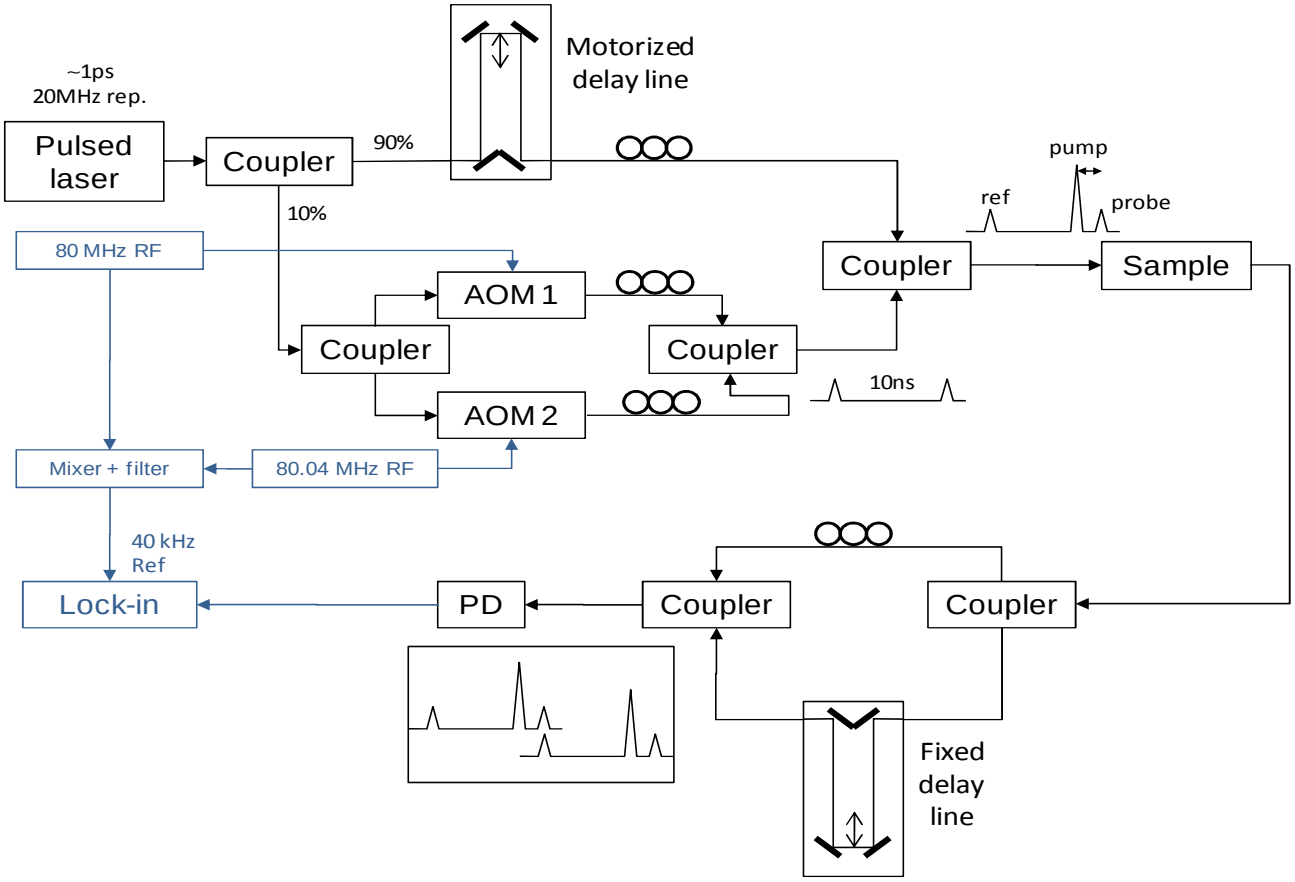
- In addition to SWNT thermal conductivity → slow (CW) switching effect
- Looking for SWNT ultrafast effects

Pump-probe pulse set-up

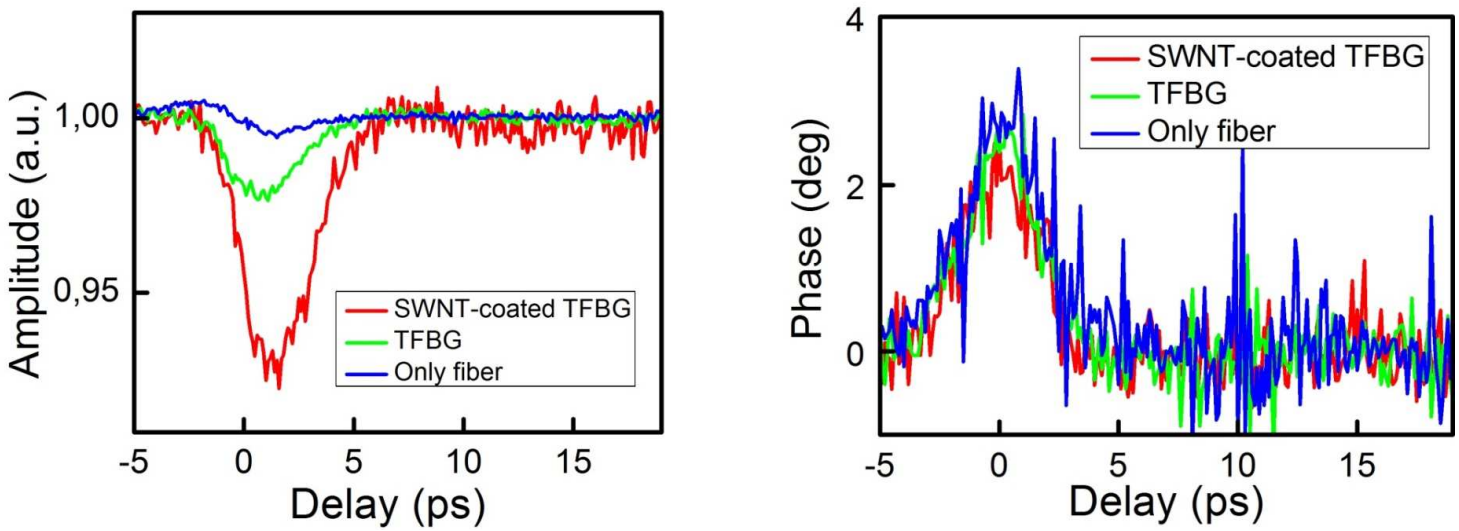


Nonlinear experiment

- Pump-probe phase sensitive set-up



Nonlinear experiment



- Temporal resolution limited by pulse width (1ps)
- Amplitude modulation of 6% (12% in intensity)
- Different configurations in source wavelength and polarization of pump and probe pulses
- Not straightforward effect in pulse transmission

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Conclusion

- SWNTs constitute an efficient nonlinear material for optics
- Interest in approaches for integrating SWNTs in fiber devices
- A solution based on a SWNT-coated TFBG-written optical fiber is presented
- Two different deposition techniques have been carried out:
  - Dipping: high layer uniformity, thickness controlled
  - Wrapping: thicker SWNT coating, simple implementation
- Ultrafast nonlinear effects have been demonstrated by pulse-probe experiment

Thank you for your attention

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