Development of Carbon Nanostructure-based Photonic and Multifunctional Materials for Space Applications

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Canada

The Canadian Space Agency

John H. Chapman Space Centre

David Florida Lab

- HQ in Saint-Hubert, Quebec;
- A world class testing and integration facility - the David Florida Laboratory, located in Ottawa;
- Offices in Ottawa, Washington, Houston and Paris;
- Responsible for managing Canada's national space programs including participation at ESA;
- Staff of approx. 350 including scientists, engineers and administrators;
- Total yearly budget of $300M.

Who we are...

OUR MANDATE

- ***Development and application of space science and technology to meet Canadian needs;***
- ***Development of an internationally competitive space industry.***

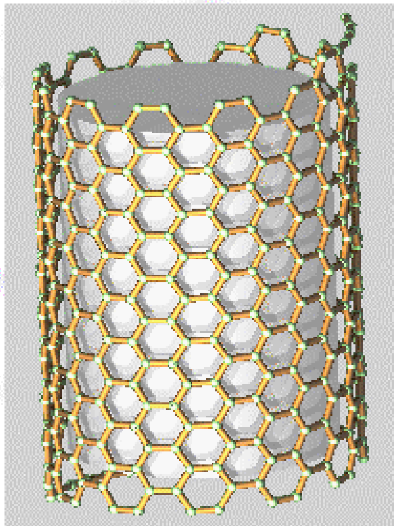
CSA ASC

Space Technology
Materials & Thermal group

- Conduct in-house R & D projects in the area of advanced materials and thermal control technologies.
- To promote research collaboration among CSA, other organizations and industry in the area of material science and engineering to meet the needs of future Canadian space program.
- Conduct in-house R & D projects in thermal technologies and to provide simulated space environment for satellite sub-systems and component testing.

Carbon Nanotube

- Extended Fullerene
- Exceptional mechanical properties
- Exceptional electro-conductive properties
- Exceptional thermo-conductive properties
- Exceptional third order nonlinear optical susceptibility



CNT-based materials R & D activities at CSA

- Collaboration with INRS of University of Quebec in synthesis and production of carbon nanotubes
- Application of carbon nanotube material for fast all-optical switches
- Application of carbon nanotube doped liquid crystal for holographic beam control elements
- CNT-polymer composite in collaboration with IMI/NRC

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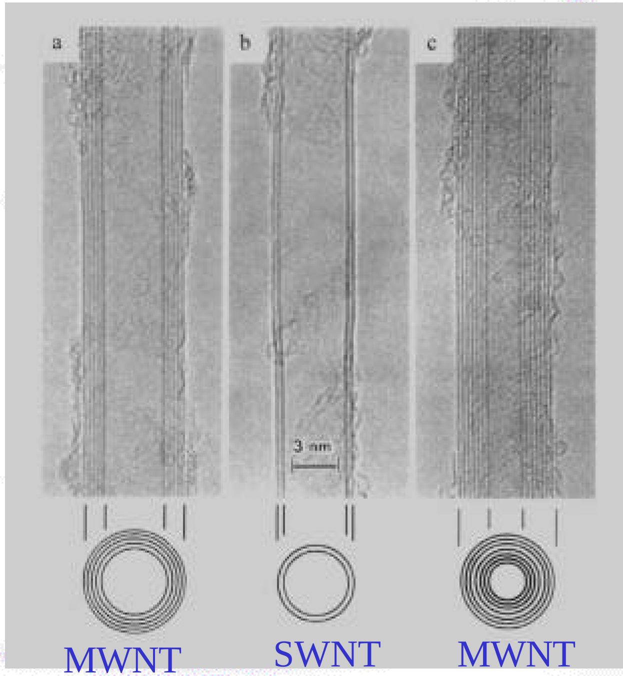
Synthesis and production of Carbon nanotubes

INRS produces CNT using three processes:

•Laser Ablation:
- 1 g/day
- 75% SWNT

•Atmospheric Plasma Torch:
- 1 g/minute
- 25% SWNT

•Ohmically Heated Carbon Paper:
- MWNT film deposition



High resolution transmission electron microscope showing the structures of carbon nanotubes (S. Iijima, 1991)

CSA ASC

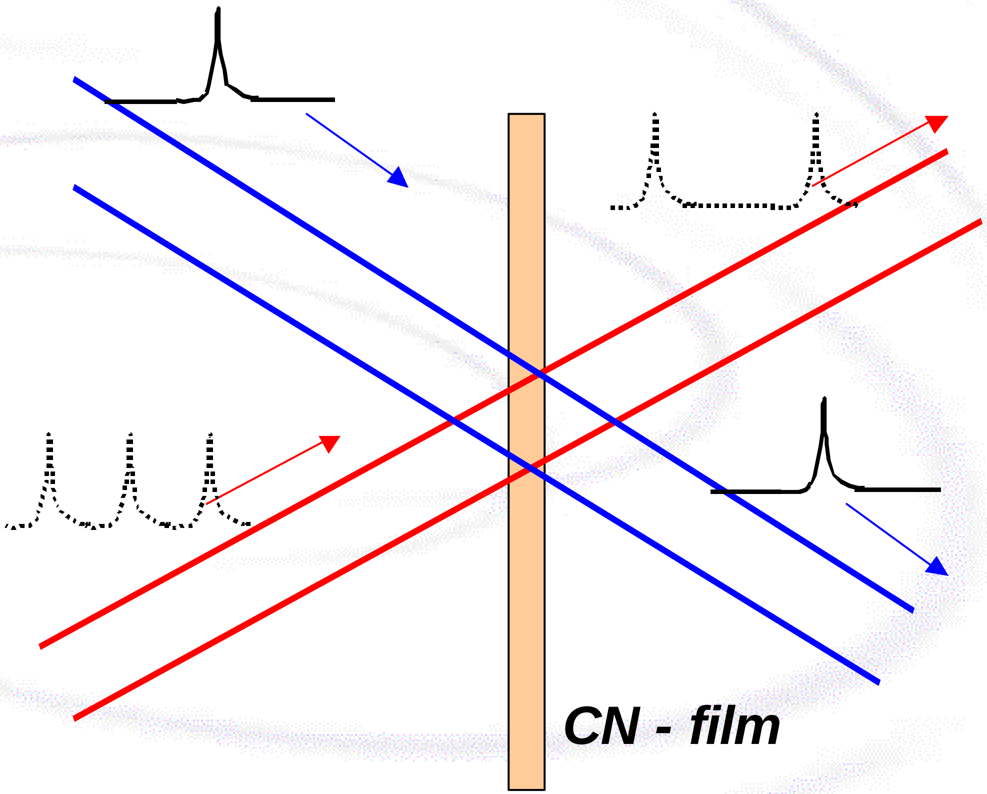
Application of carbon nanotube material for fast all-optical switches

- Exceptional nonlinear optical susceptibility of Carbon Nanotubes

- High delocalization of π-electrons in CNs causes high $\chi^{(3)}$
- Similar to advanced polymers ($\chi^{(3)} \sim 10^{-10} - 10^{-9}$ esu).
- Sub-picosecond decay time

CNTs for all-optical switches

- High-bit-rate time-division-multiplexing optical communication systems
- Optical-digital computing systems



Application of carbon nanotube doped liquid crystal for holographic beam control elements

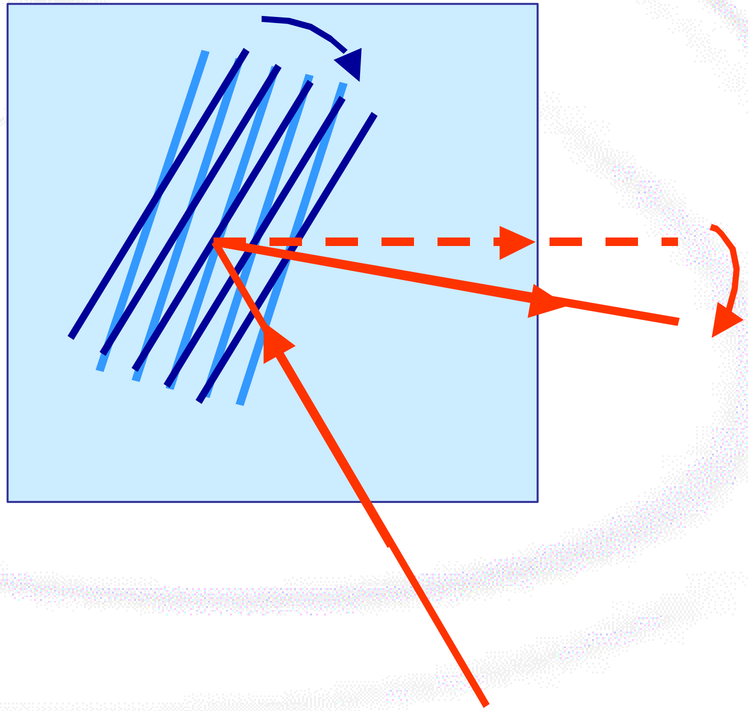
- As part of this activity at CSA is to develop a free space laser communication system
- Carbon nanotubes may enhance inertial optical nonlinearities of liquid crystal through a doping mechanism
- Extremely high optical nonlinearity as large as 20 cm^2/Watt was demonstrated in the liquid crystals doped by carbon nanotubes

Applications of "giant" inertial nonlinearities

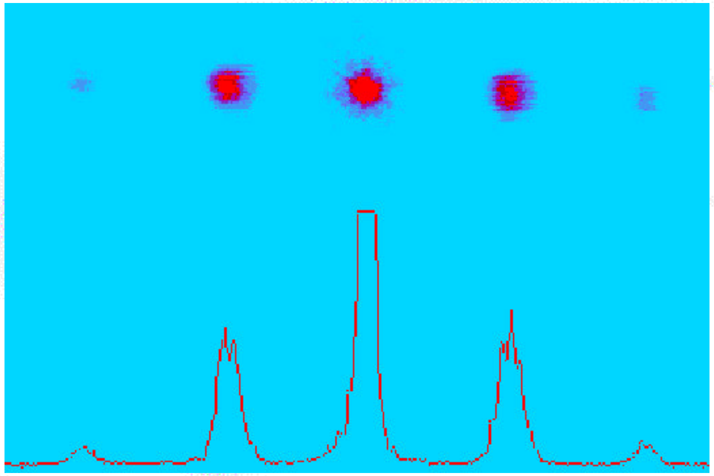
- Optical limiting
- Phase conjugation
  - Correction of phase distortions in communication lines, lasers, lidars and imaging
  - All-optical dynamic beam tracking/control
- Optical holographic memory

All-optical dynamic beam control

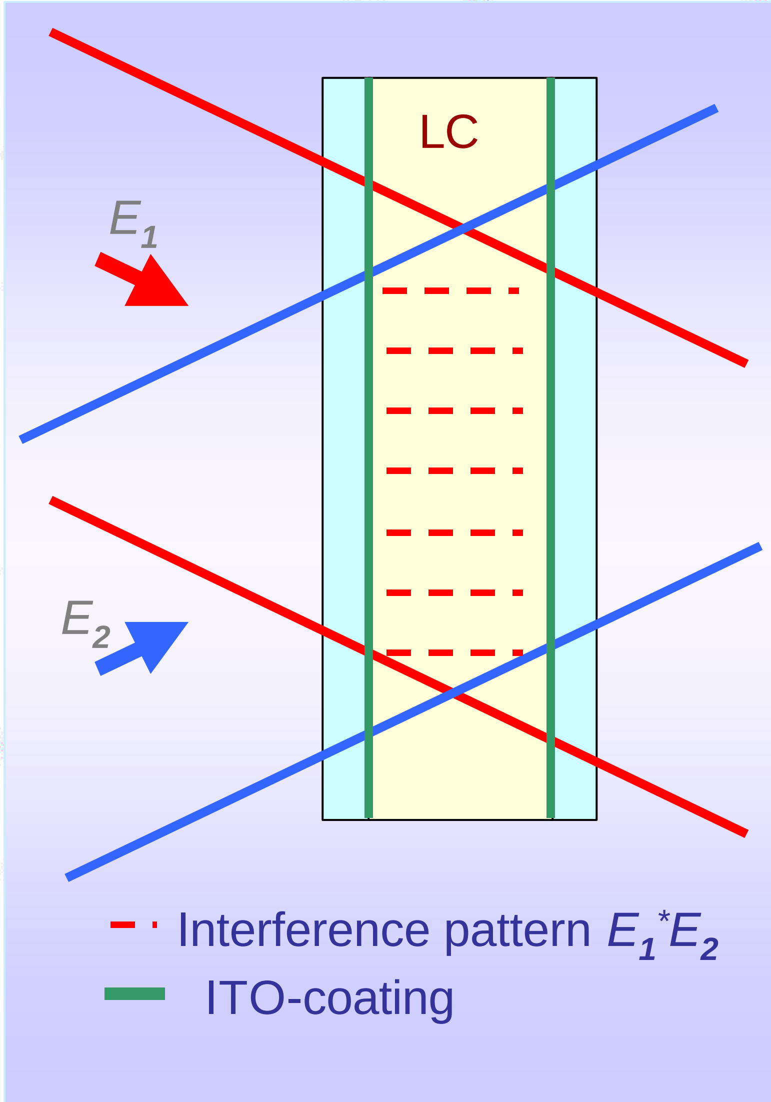
- Steering accomplished by light-induced dynamic hologram
- No mechanical inertia
- Reorientation time can be as low as few microseconds



Hologram writing/reading at 1500 nm

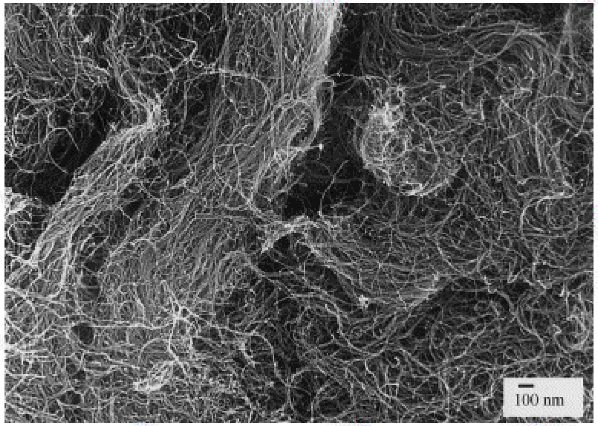


Diffraction of He-Ne beam (633 nm) by the hologram written by 1500 nm beams: center – not reflected part of reading beam 3, at the sides – reflected beam 4 (first and second orders of diffraction) .



CNT-polymer composite

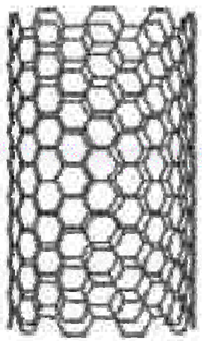
- Single-wall carbon nanotubes (SWCNT)
  - Produced by Steacie Institute, NRC
  - Laser grown
  - Purity: >95% CNT
- Epoxy matrix
  - Bisphenol A epoxy (Shell Epon 828)
  - Polyamine hardener (Shell Epicure 3046)



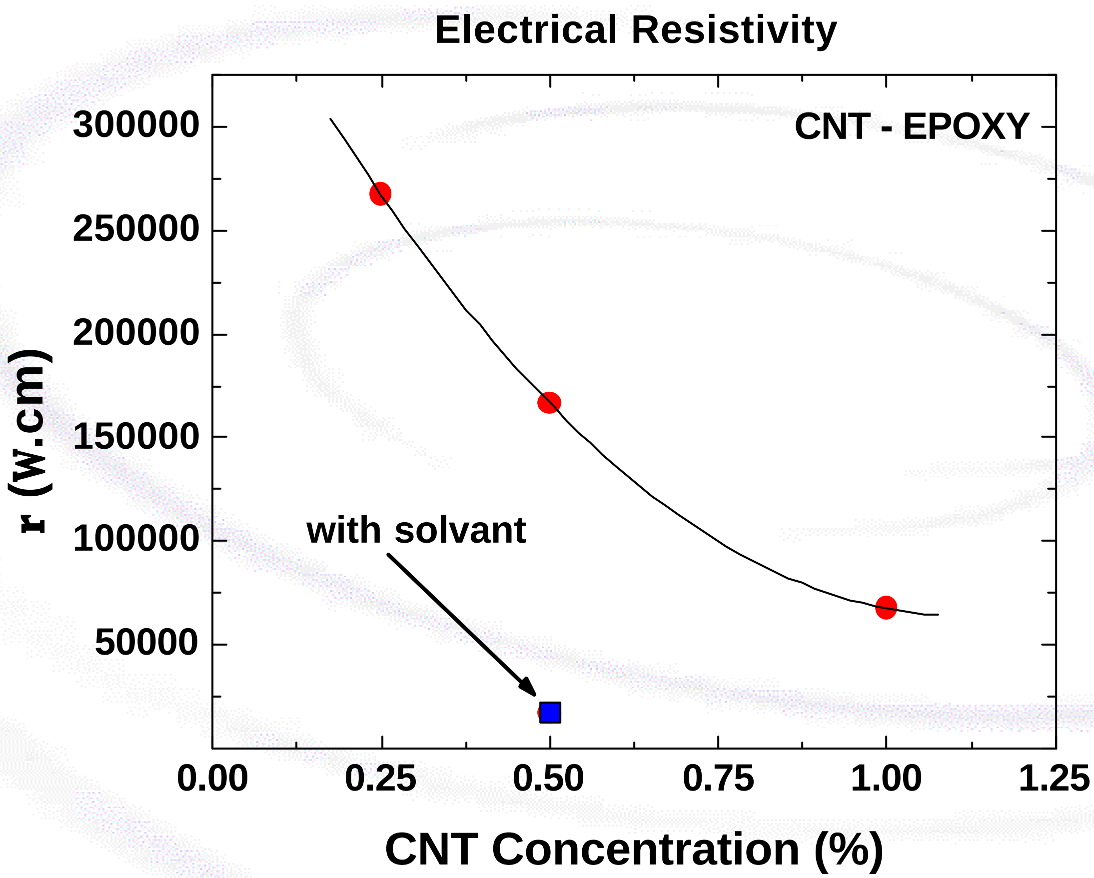
Catalytically-grown nanotube material

Material	**D** *nm*	**TS** *GPa*	**TM** *GPa*	**Aspect ratio**
SWNT	**1**	**30**	**1000**	**n.a.**
MWNT	**2-50**	**26**	**1000**	**n.a.**
NF	**50-200**	**7**	**600**	**100-500**

n.a. : not available



Electrical resistivity of CNT-Epoxy composite

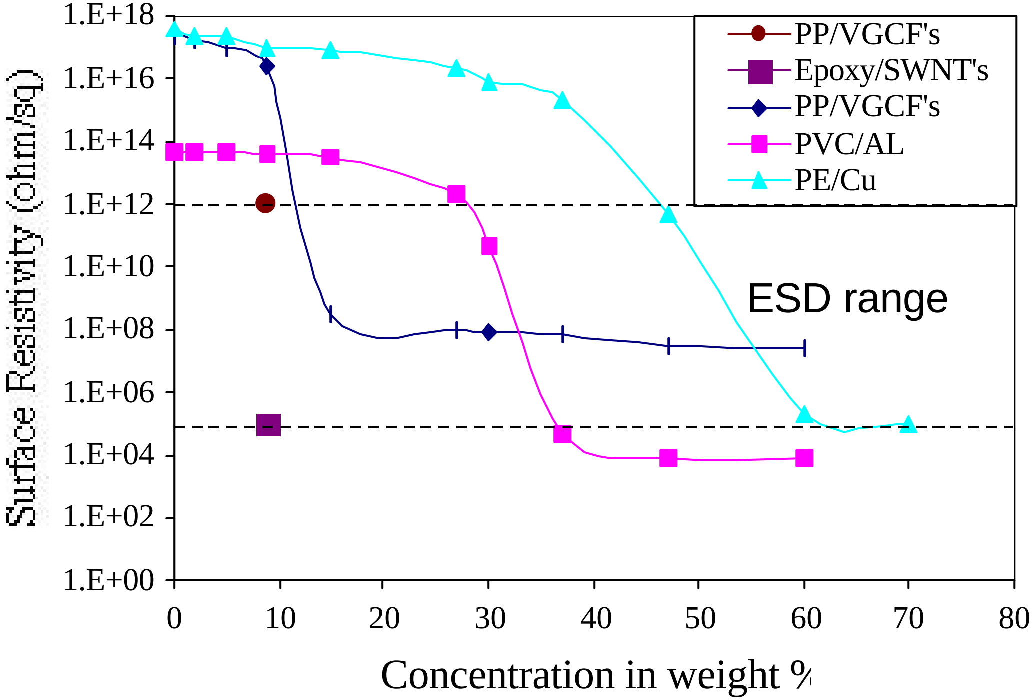


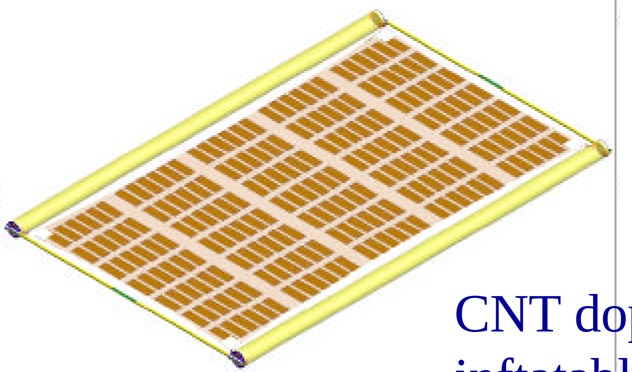
Potential Space Applications of CNT-polymer Composite

- CNT conductive polymer - ESD and EMI Materials

Limitations of current ESD Materials:

- Instability
- No enhanced mechanical strength
- Requires deposition of conductive coating





CNT doped polymer thin film for inftatable membrane antennas

Potential Space Applications of CNT-polymer Composite

- High performance structural material for spacecraft and payloads
  - Super strong and stiff structural material for launch vehicle and spacecraft
  - Application in MEMS

Conclusions

- CNT based R&D holds promising potential applications in Photonic and Multifunctional Materials for space applications.

- CSA is looking forward to collaborate with other international partners in the area of CNT-based optical switches and on smart material applications.

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