Raman Spectral features of single walled carbon nanotubes synthesized by laser vaporization

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NLC

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Raman scattering in SWCNTs

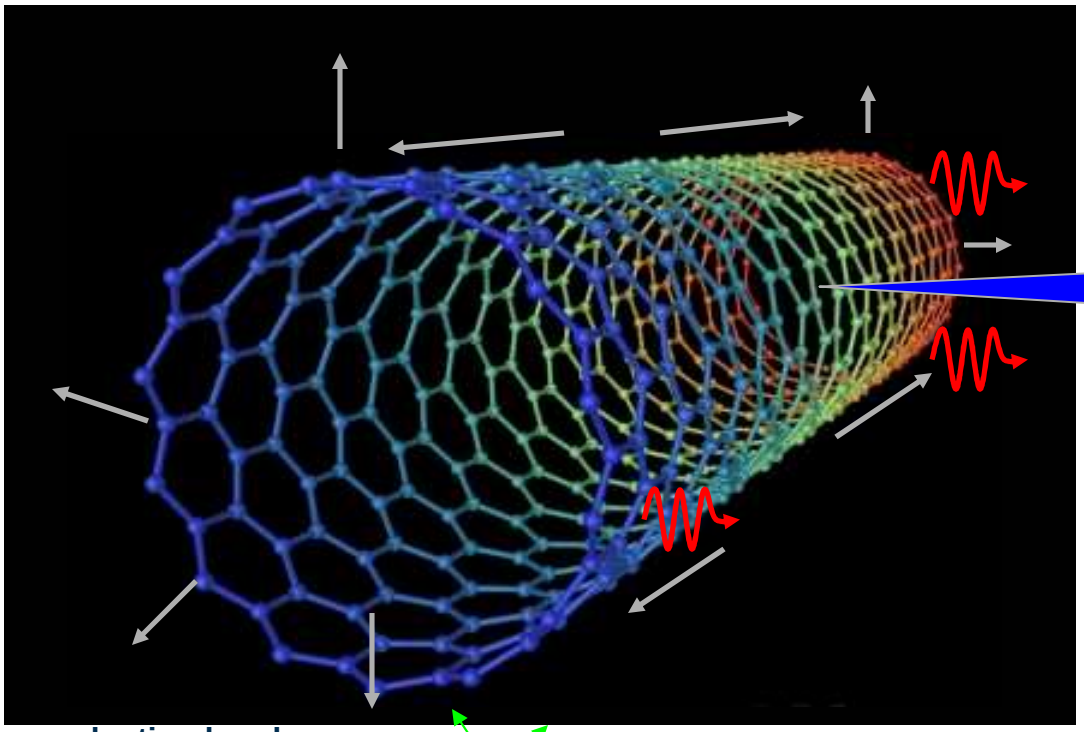
- In Raman spectra of SWCNTs there many features which can be identified with specific phonon modes and with specific Raman scattering processes that contribute to each feature

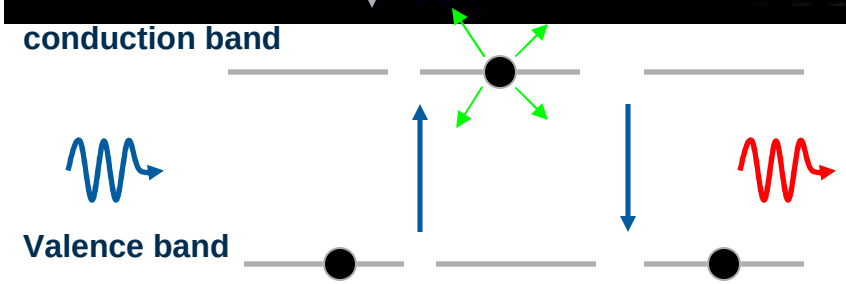
- The Raman spectra can provide us with info about the exceptional 1D properties of nanotubes. These include:
  - Phonon structure
  - Electronic structure
  - Defects with the nanotubes

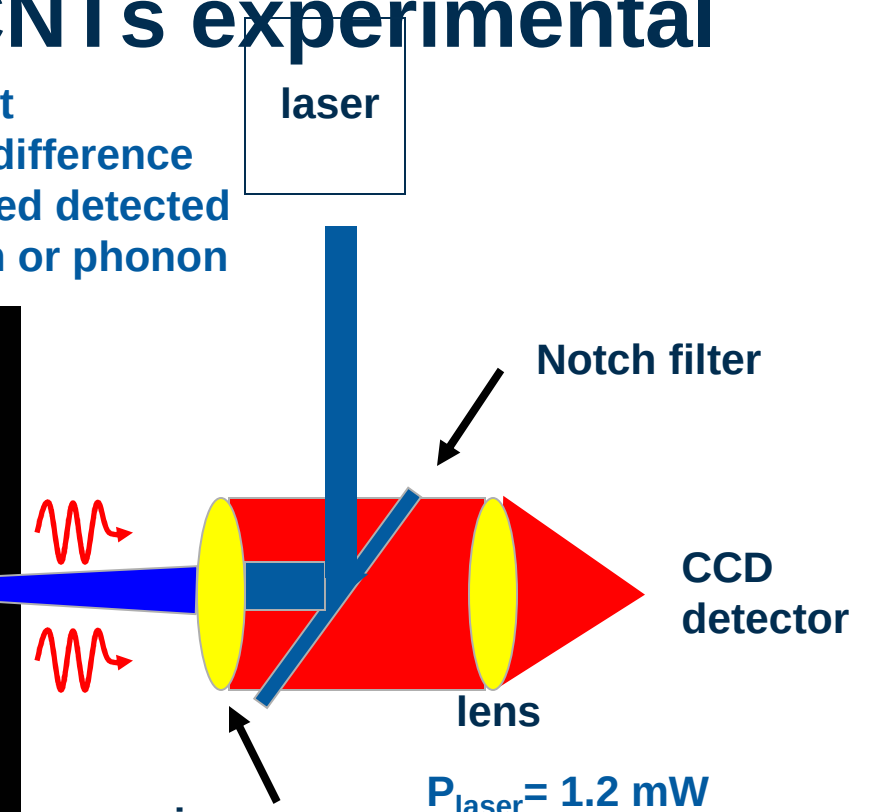
- Mechanical properties, elastic properties and thermal properties are strongly influenced phonons. Thus, Raman spectra provide a very detailed info on the properties of SWCNTs

Raman scattering in SWCNTs experimental

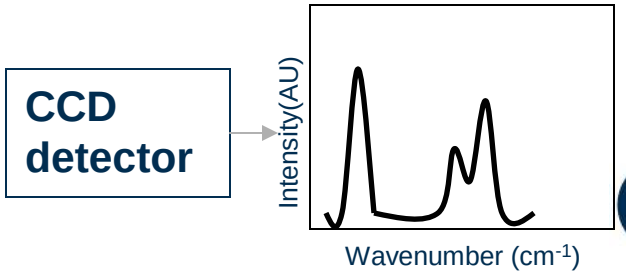
- Raman scattering is the inelastic scattering of light
- Raman frequency plot is a measure of the energy difference between the laser excitation photon and the scattered detected photon ie it measures the frequency of the vibration or phonon





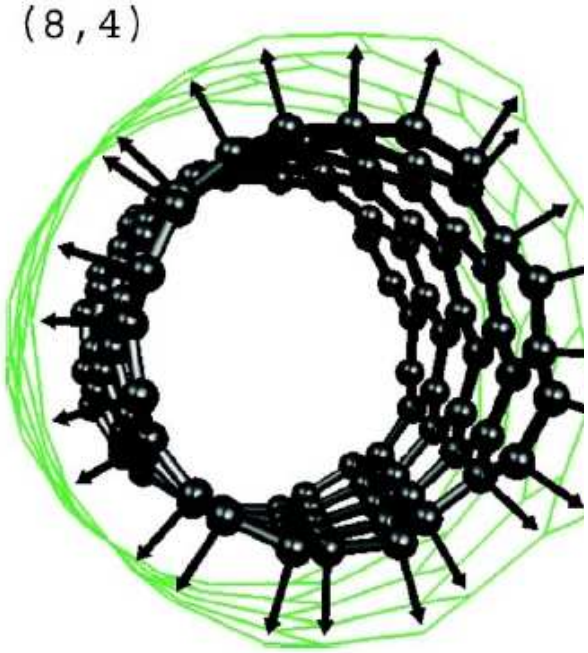


P_{laser}= 1.2 mW
T= 180 s
Spot size= 120 micron
20x objective on microscope



Radial Breathing Mode (RBM)

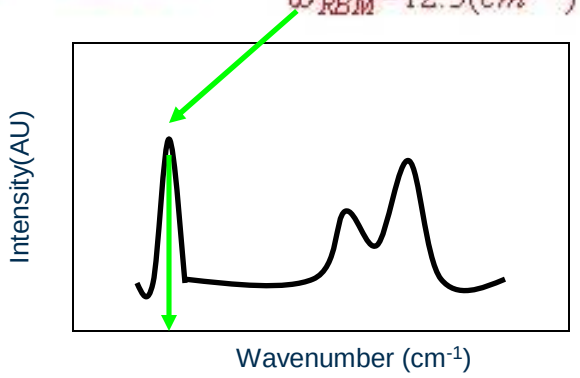
- this frequency mode determines whether there is SWCNTs in the sample
- diameter and diameter distribution can be determined



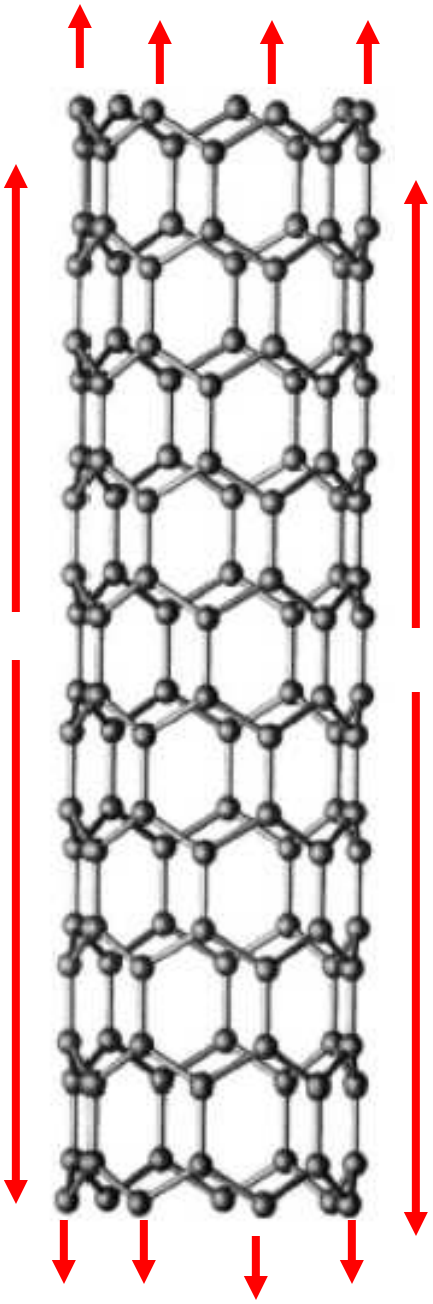
$$d_t(nm) = \frac{\sqrt{3}\,a_{c-c}\sqrt{(m^2+nm+n^2)}}{\pi} = \frac{C_h}{\pi}$$

where d_t is diameter of the nanotube in mn a_{c-c} is the c-c distance and (n,m) is the indices decribing the nanotube. C_h is the chiral vector. The chiral angle is given by: $\theta = \tan^{-1}\frac{\sqrt{3}\,n}{2m+n}$. The diameter can be determined from the plot by:

$$d(nm) = \frac{223.5(cm^{-1})}{\omega_{RBM} - 12.5(cm^{-1})}$$

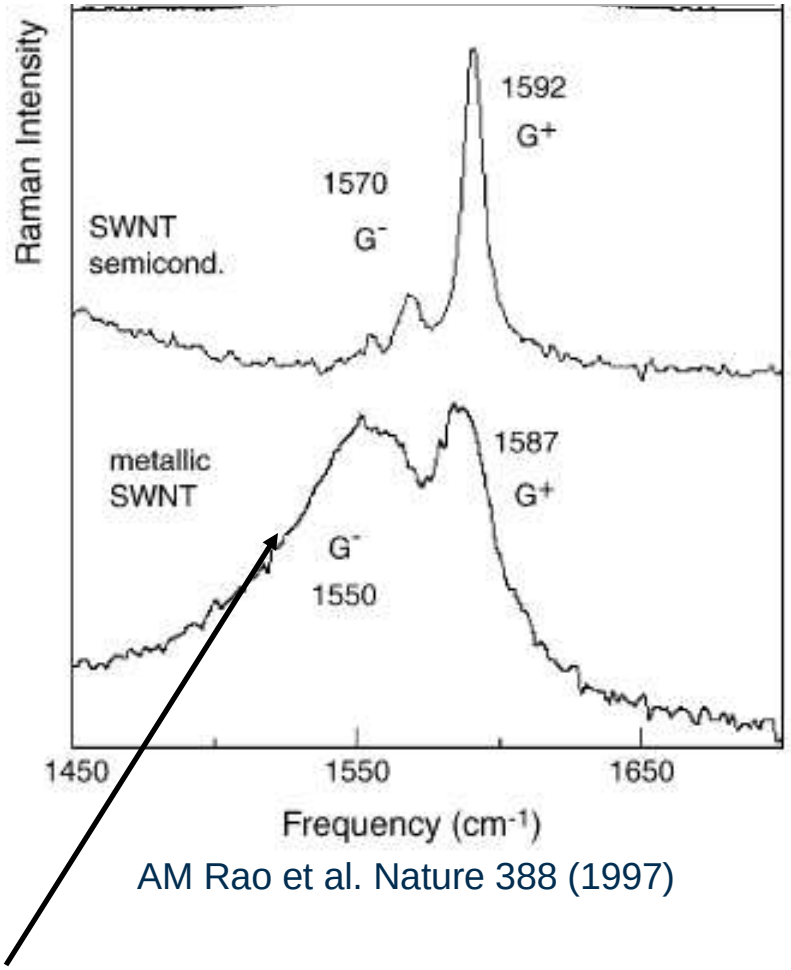


Tangential stretching mode-in plane



When semi-conducting

When metallic



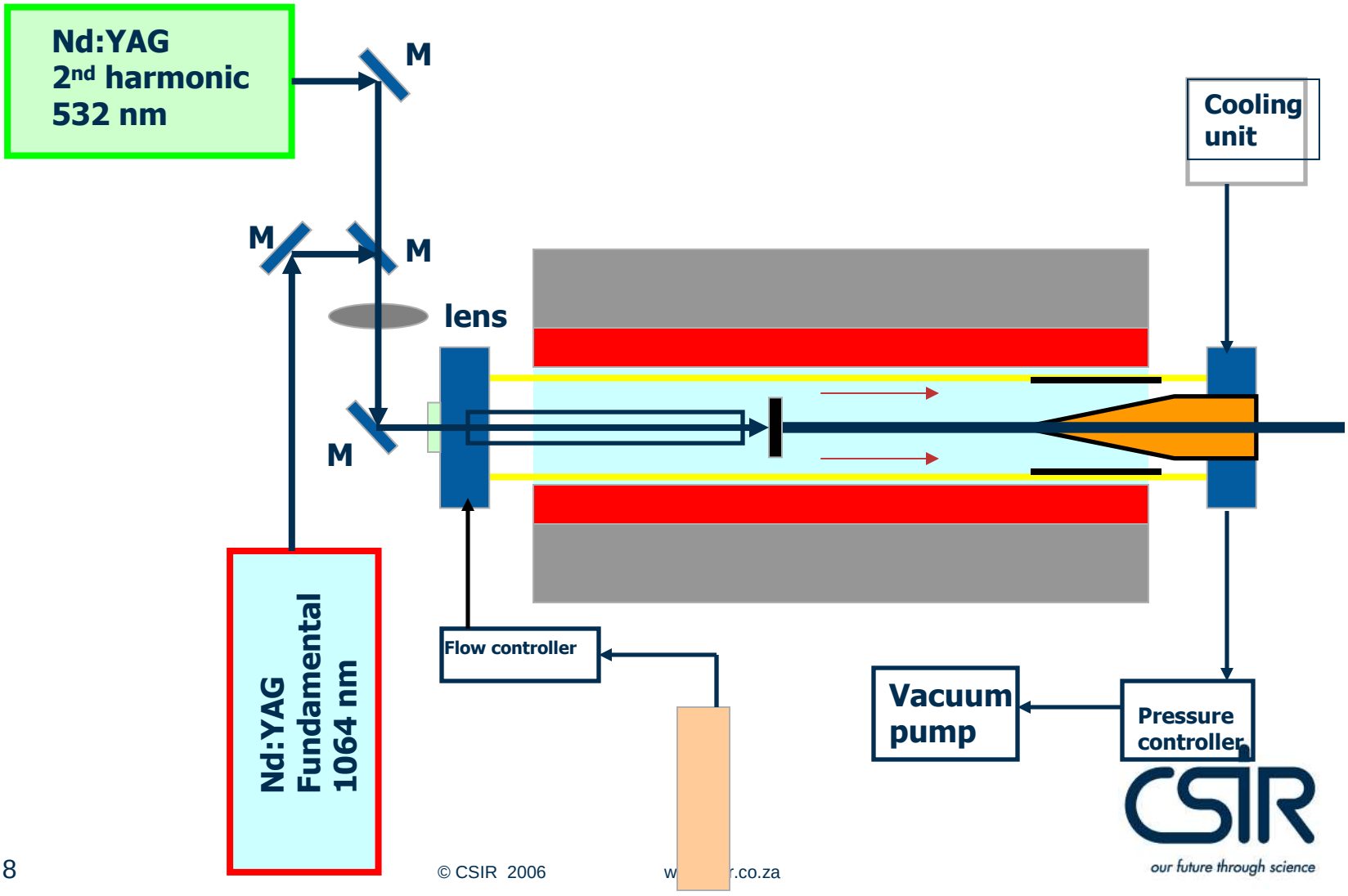
AM Rao et al. Nature 388 (1997)

$$\mathrm{BWF}(\omega) = I_0 \frac{(1 + (\omega - \omega_0)/q\Gamma)^2}{1 + ((\omega - \omega_0)/\Gamma)^2}$$

Experimental

Experimental

Set-up



Experimental.....cont.

Experimental parameters

- two laser combined and vaporize a composite target
- target in a tube furnace in continuous flow of Argon
- temperature kept at 1000 ^{O}C
- Ar flow of 200 sccm
- Pressure at 375 Torr
- fluence at target: 2 J/cm^2
- targets composition is:

Experimental….cont

Target composition

Sample Label	Composition(%)	Temperature(^{0}C)
Sample 1	**98%C:1%Ni:1%Co**	1000
Sample 2	**98%C:0.67%Fe:0.67% Ni:0.67%Co**	1000

Results and Discussion

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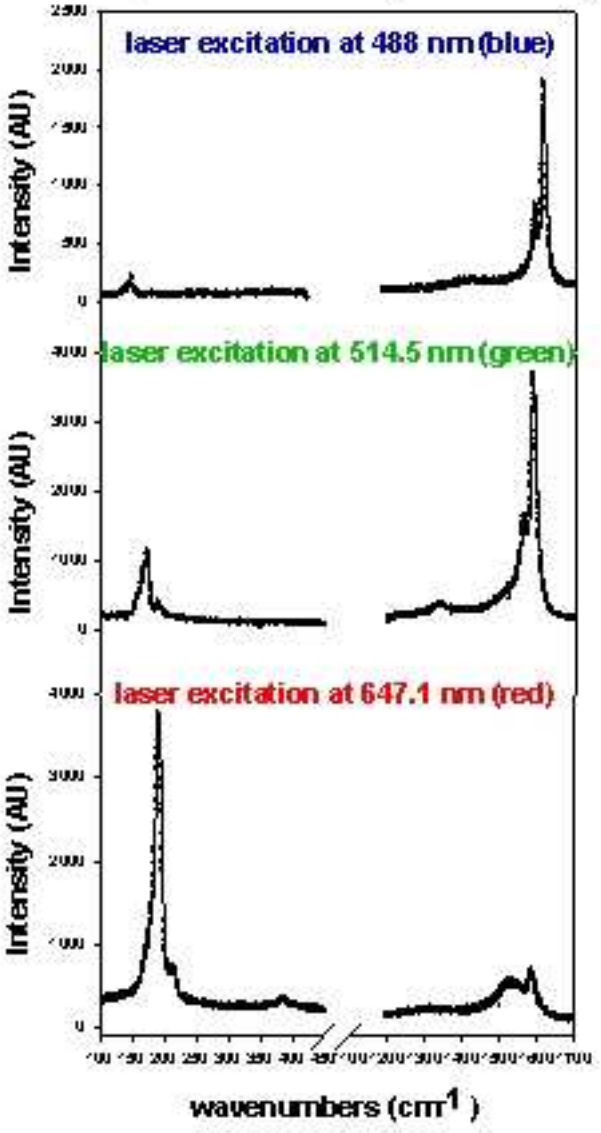
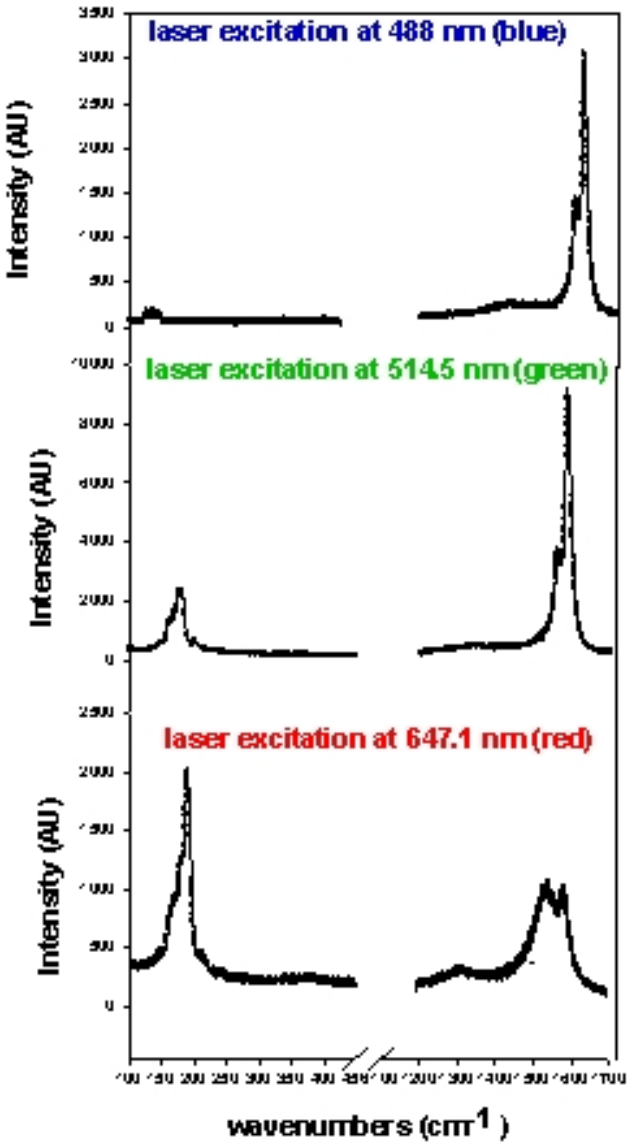
Sample 1: C:Co:Ni (98%:1%:1%)

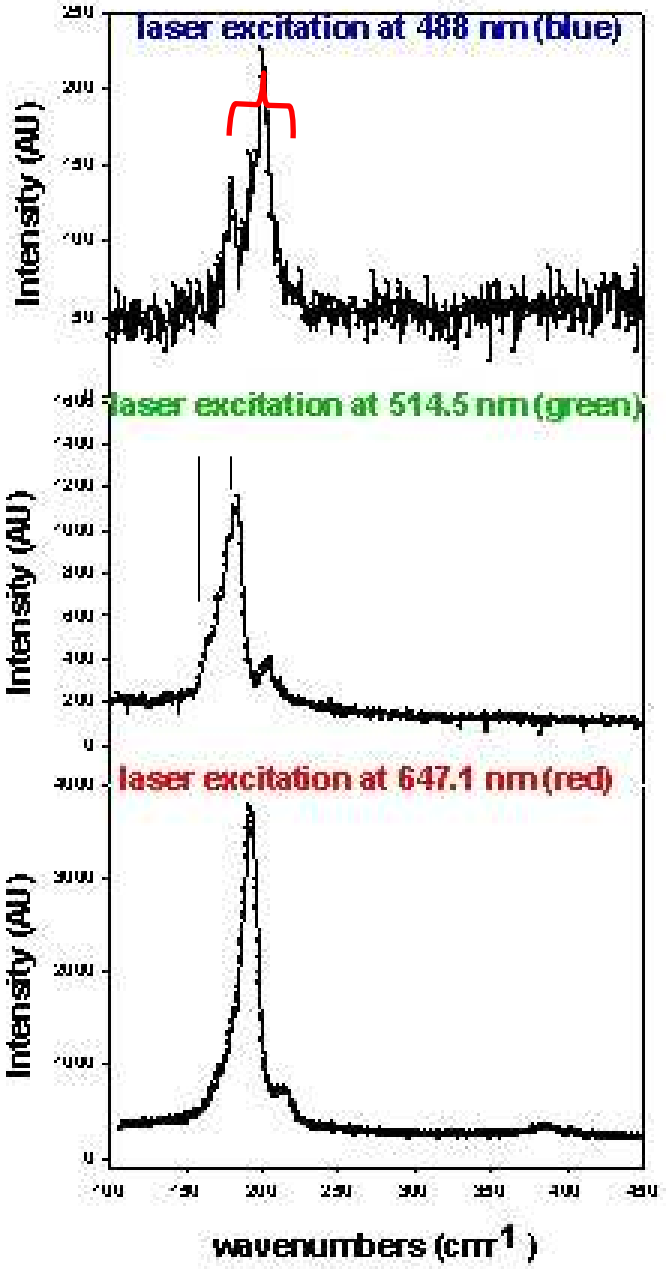


- more swcnt in sample 2
- longer swcnt as seen by higher intensities of the G band

Sample 2: C:Fe:Co:Ni (98%:0.67%:67%:0.67%)



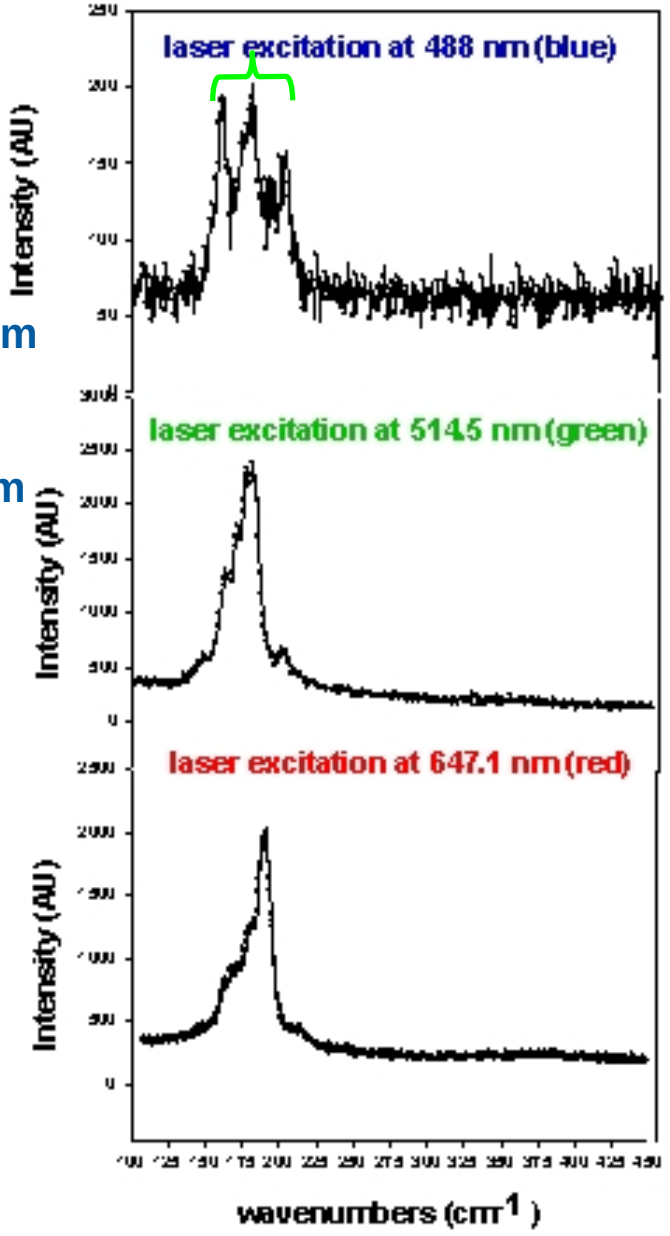
Sample 1: C:Co:Ni (98%:1%:1%)
Radial Breathing Mode



Sample 1:
D_t= 1.31-1.46 nm

Sample 2:
D_t= 1.33-149 nm

Sample 2: C:Fe:Co:Ni (98%:0.67%:67%:0.67%)
Radial Breathing Mode (RBM)



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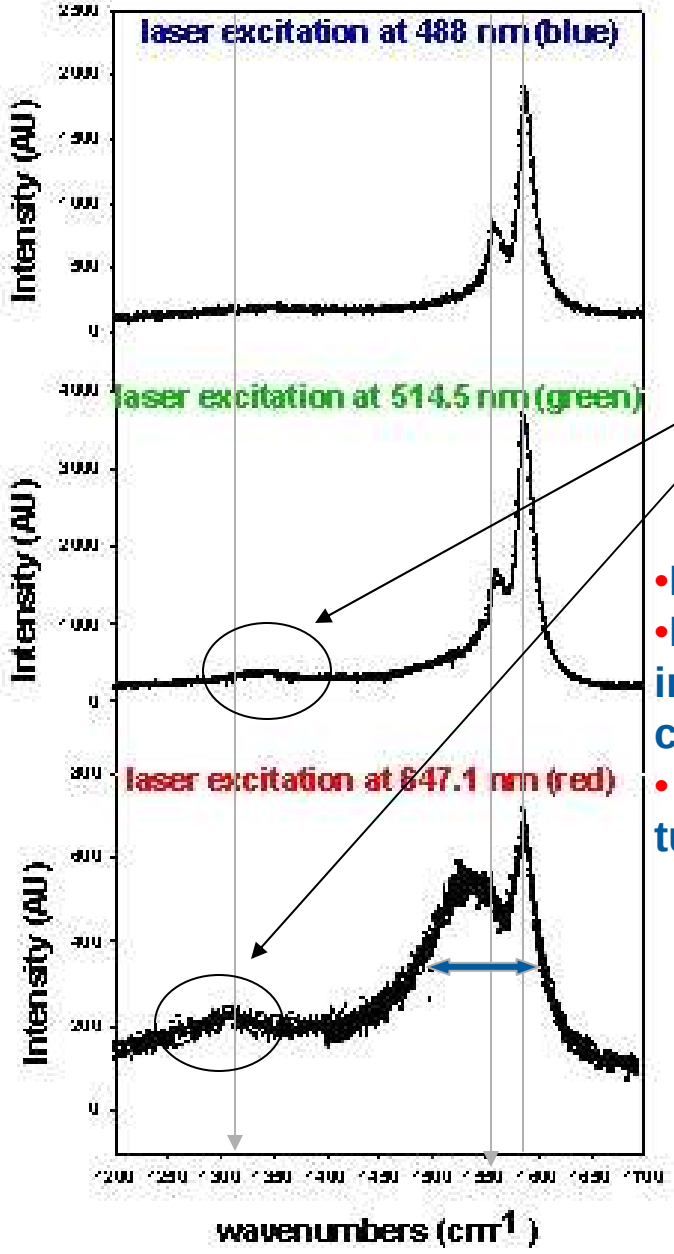
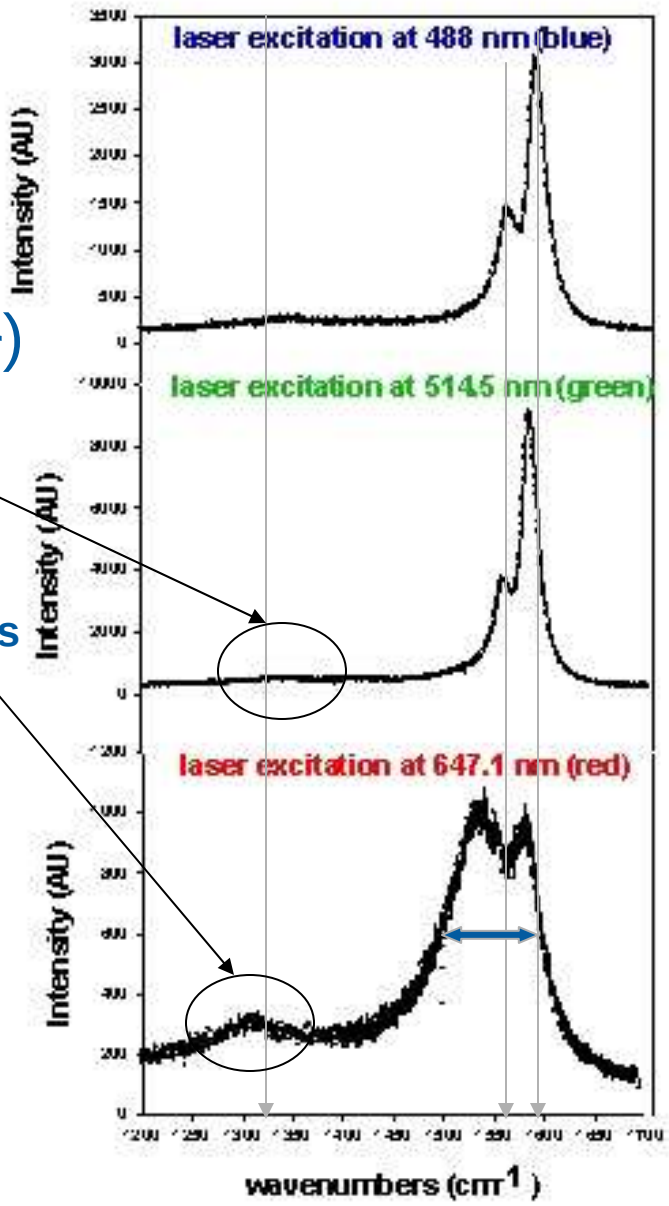
Sample 1: C:Co:Ni (98%:1%:1%)
D and G band



D band (disorder)

- Lower defects?
- Narrower linewidths indicate improved crystallinity
- semiconducting tubes favoured

Sample 2: C:Fe:Co:Ni (98%:0.67%:67%:0.67%)
D and G band



Conclusions

- Important spectral features of SWCNTs discussed
- Raman spectroscopy was applied to as prepared laser synthesized SWCNTs
- The Raman spectra revealed the presence of SWCNTs with low defect concentration.
- Adding a third catalyst to the composite target
  - ❑ increased the yield as indicated by higher Raman intensities
  - ❑Longer tubes where synthesized as indicated by stonger G band intensities
  - ❑Tubes with larger diameters were synthesized
  - ❑Semi-conductor tubes were favoured
  - ❑Improved crystallinity as indicated by narrower line-widths.

Thank You

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CSIR
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