The density of vibrational states of carbon nanotubes is of great interest. First, one would like to compare experiment to various theories, most of which are based on simple force constant models. Second, one would like direct evidence for 1-D phonon subbands (analogous to the much-publicized 1-D quantum-confined electronic subbands). Their presence is inferred from our recent measurement of low-T heat capacity (“Quantized phonon spectrum of single wall carbon nanotubes”, J. Hone, B. Batlogg, Z. Benes, A. T. Johnson and J. E. Fischer, Science 289, 1730 (2000). Third, in that paper we present clear evidence for coupling effects between tubes - these so-called "ropes" result from self-assembly during growth, and are enhanced by subsequent high temperature annealing. The heat capacity implies for example that the lowest 1-D phonon subband is stiffened by more than a factor of 2 with respect to theory for an isolated tube. This subband corresponds at Q = 0 to the tube “squashing” mode, which is clearly hindered if the tube is surrounded by other tubes in VDW contact. This mode is Raman-active but lies around 20 inverse cm. and therefor has escaped detection. Finally, we measured the VDOS using classical inelastic neutron scattering (“Phonon density of states of single wall carbon nanotubes”, S. Rols, Z. Benes, E. Anglaret, J. L. Sauvajol, P. Papanek, G. Coddens, H. Schober, S. Ivanov, J. E. Fischer and A. J. Dianoux, Phys. Rev. Lett. in press) and saw no evidence for these subbands. We tried extracting q-dispersion information from neutron TOF data in order to emphasize any possible signs of these subbands, to no avail.

IXS offers several advantages for this problem, in particular the use of smaller samples. This permits a) to minimize problems with polydispersity (x-ray diffraction on mg. quantities is always sharper than neutron diffraction on a gram); and b) the ability to measure S(Q,omega) on “advanced” nanotube materials, hopefully less polydisperse, which are only available in small quantities.

After detailed discussions with Harald Sinn and Ercan Alp, we propose the following trial experiment. Randomly oriented nanotubes with average diameter 1.4 nm will be pressed into a stainless steel thin-wall tube 2 mm diameter by 10 mm long. We should be able to get to 50% filling without trouble. This will give us about 30 ml. total volume containing about 22 mg. of nanotubes. The end of the stainless container will be closed off with thin Kapton tape. With standard focussing (250 x 250 micron spot) and 21 keV incident energy, we can explore the Q range 0.2 - 0.4 inverse angstroms and try different Q resolutions. We request 2 days for this trial experiment. If successful, follow-on experiments will use microfocussing and oriented nanotube films to obtain dispersion curves along and parallel to the nanotube axes. Long range, we will look at nanotube materials with different degrees of crystallinity, to “tune” the effect of intertube interactions on the low-lying modes.