ACOUSTIC PHONONS PROBE THE MECHANISM OF DNA MELTING

Understanding the function of biological molecules has evolved from being structure-based to including a knowledge of molecular dynamics [1]. In the case of deoxyribonucleic acid (DNA), a key point of interest is base-pair opening as such dynamics play a key role in replication, transcription and denaturation [2]. These processes all involve the splitting of the double helix into single strands, which is thought to be initiated locally by the breaking of inter-base hydrogen bonds and the formation of bubbles spanning several base-pairs. Bubbles can be probed by the longitudinal acoustic phonons along the DNA helix, which measure the coherence length of the intact double strands. Here we report our first variable temperature IXS measurements, performed in March 2010, IXS being the technique of choice since INS measurements above room temperature are broadened by quasi-elastic scattering. Our on-going interest in the dynamics of DNA coincides with recently published work on the microscopic flexibility of DNA [3,4].

INS [5] and IXS [6] (and atomistic simulations [7]) reveal two, related, acoustic-like phonons. IXS measures the dispersion in the Brillouin zone defined by the separation between base-pairs (~3 Å), the BZ width is 1.8 $Å^{-1}$. INS measures the acoustic phonons of the DNA helix in a Brillouin zone of width 0.18 $Å^{-1}$, defined by the helix pitch, 33 Å. The goal of this IXS experiment was to measure at the lowest possible Q value so as to be in the first Brillouin zone of the helix.

Using the Si(11,11,11) setup, the acoustic phonons were measured, from a lowest Q value of 0.9 nm^{-1}, from room temperature up to 356 K (see Figure 1 and 2). At the highest temperature the DNA should have melted but the spectra and dispersion curves suggest otherwise. The experiment was performed in a sealed sample holder, as for neutron scattering experiments. However the free volume in the IXS sample holder is relatively larger than in the neutron case, allowing the sample to dry, which was revealed by a marked loss in intensity of the base-pair Bragg peak. The sample removed from the sample holder was brittle but could be restored by humidifying it with D_2O, once again giving a good diffraction peak. In order to investigate loss in correlation upon melting, this data has to be measured through melting under controlled humidity.

Further tests were subsequently performed in low flux mode (May 2010) in which the Bragg peak was measured as a function of temperature, with the sample volume open to a reservoir of saturated salt solution at (i) ambient temperature, and (ii) approximately the same temperature as the sample. In both cases the Bragg peak better withstood heating but it still lost intensity with increasing temperature. The reasons however are different in each case. In (i) the sample tended to dry out, whereas in (ii) the sample became overly wet. A more accurate temperature control has now been developed for the reservoir and tests will be performed in low flux mode on ID28 at the start of October. We have also modified the sample holder to reduce the relative free volume and tests will also reveal whether the sample holder can now be used 'closed'.

We are confident that we will be able to control the sample humidity as a result of the tests and would like to pursue these measurements to determine the position and width of the IXS peaks through melting, giving invaluable data on the way coherence lengths and associated structure change on melting.

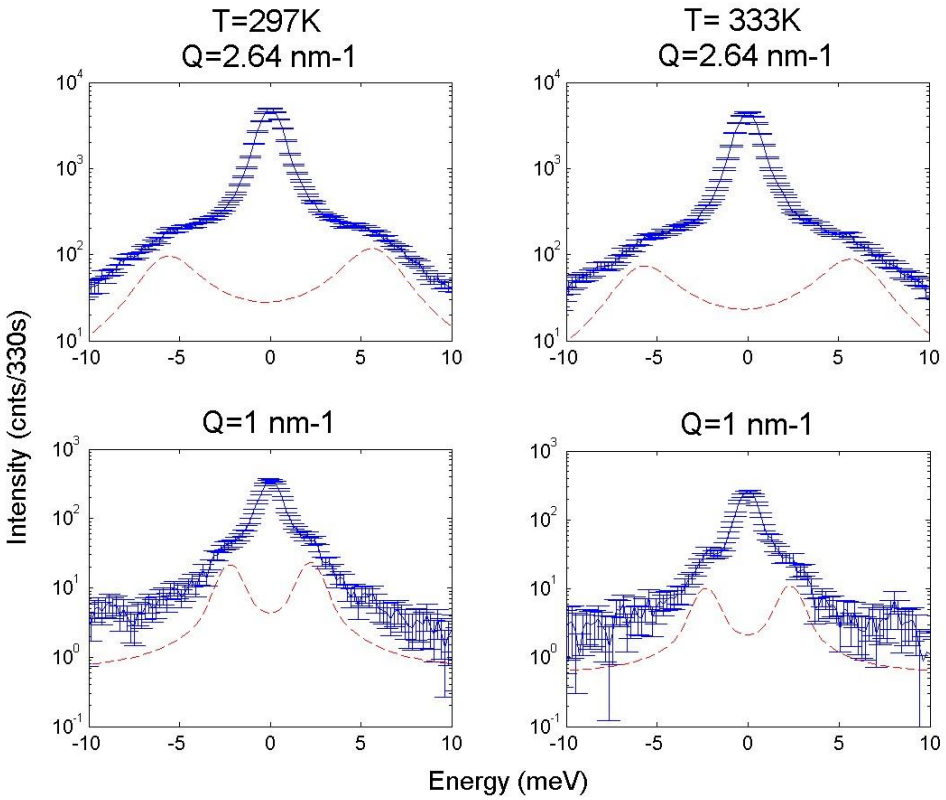

Figure 1: Selection of spectra with fitted excitations as a function of Q and T

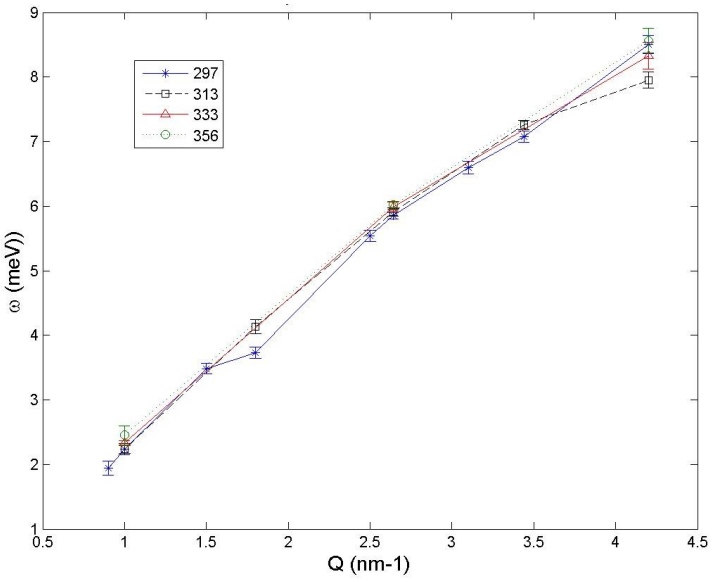

Figure 2: Dispersion curves obtained by fitting spectra at four temperatures

***References**:* [1] M. Peyrard, Nature Physics 2 (2006) 13 [2] T. S. van Erp et al., Phys. Rev. Lett. 95 (2005) 218104 [3] G. Weber et al., Nat Phys (2009) DOI 10.1038/NPHYS1371 [4] S. Rebecca et al., Science 322 (2008) 446 [5] H. Grimm et al., Phys. Rev. Lett 83 (1987) 5972 [6] M. Krisch et al., Phys. Rev. E 73 (2006) 61909 [7] F. Merzel et al., Phys. Rev. E 76 (2007) 31917