We have observed strong narrowing in the inelastic X-ray scattering (IXS) spectra of liquid (l-) Se at the momentum transfer $Q$ between 12 and 15 nm$^{-1}$ [1]. Typically, in simple monatomic liquids, narrowing is observed at the first structure factor maximum, in this case, about 19 nm$^{-1}$. However, we see it at a somewhat lower $Q$. This is probably related to the covalent nature of the liquid. Se forms two-fold coordinated linear chain molecules, where atoms are covalently bonded. Crystalline Se with a trigonal form is stable at ambient conditions and it consists of helical chains, while metastable monoclinic forms consist of Se$_8$ ring molecules. When Se is melted, its two-fold coordinated chain structure is largely preserved and l-Se consists of disordered long chains where segments with a helical chain-like configuration (a) and ring-like one (b) are randomly distributed (see Fig. 1).

We measured the dynamic structure factor $S(Q,E)$, where $E$ is the energy transfer, using a high-resolution IXS spectrometer at beamline BL35XU. The energy of the incident beam was 21.747 keV and the spectrometer resolution depending on the analyzer crystals was 1.5 - 1.8 meV in the present experimental setup. The Se sample of 99.999% purity and 0.04 mm in thickness was mounted in a single-crystal sapphire cell. IXS spectra of l-Se at 523 K were measured from 1.8 to 42 nm$^{-1}$ over 40 meV.

Figure 2 shows the overall features of the $S(Q,E)$ of l-Se at 523 K. The energy integrals of $S(Q,E)$ become the static structure factor $S(Q)$, which agrees well with that obtained from neutron scattering (NS) [2] as shown in Fig. 3(a). $S(Q,0)$, shown in Fig. 2, has a sharp first peak at 15 nm$^{-1}$, which is a little smaller than the first $S(Q)$ maximum. That is, the $S(Q,E)$ observed is very narrow at around 15 nm$^{-1}$.

The spectra were analyzed using a model function consisting of several Gaussians to deconvolute $S(Q,E)$ from the spectrometer resolution. Then we calculated the normalized second frequency moment of $S(Q,E)$, $\omega_0^2(Q)$, from the deconvoluted model function. Figure 3(b) shows the $E$-$Q$ dispersion relation of $\omega_0^2(Q)$ deduced from $S(Q,E)$ (triangles). The triangles reasonably follow the solid line in Fig. 3(b) that is calculated using the sum rule, $\omega_0^2(Q) = k_B T Q^2 / (m S(Q))$, where $m$ is a particle mass and $S(Q)$ is obtained from NS [2]. More exactly, however, the triangles deviate below the solid line at the $Q$ between 12 and 15 nm$^{-1}$. This discrepancy can be explained if we assume the $Q$ dependence of $m$. Figure 3(c) shows the effective mass deduced from $\omega_0(Q)$. The mass as large as 2 - 3 atoms just pinpoints the $Q$ where the strong narrowing occurs. The distance corresponding to the $Q$ is close to the fourth-nearest-neighbor distance, and it is crucial to distinguish between helical chain-like and ring-like segments in...
the disordered chain as shown in Fig. 1. Thus, the large effective mass hints that the segments cooperatively move like a rigid molecule under the propagation of longitudinal waves with the corresponding $Q$. This must be the origin of the present narrowing.

Fig. 3. (a) The energy integral of $S(Q,E)$ (open triangles) is plotted after being properly normalized. Also shown is the $S(Q)$ obtained from neutron scattering (solid line). (b) $E$-$Q$ dispersion relation of $\omega_0(Q)$ obtained from $S(Q,E)$ (open triangles) and sum rule (solid line). (c) $Q$ dependence of effective mass.