論　文　の　要　旨

氏　　名　　　　　郭　磊

論文題目　Photo-cathode Studies for High Performance Linear Accelerators
（高性能線形加速器のためのフォトカソード研究）

The accelerator has contributed greatly to the development of many scientific fields, e.g. elementary particle/nuclear physics, synchrotron radiation science including material physics, bio-science, industrial applications, medical applications, etc. Although the electron storage ring has been widely used as the advanced accelerator for electron and positron collider and the third generation light source, the beam performance of the ring is strongly limited by two aspects by the synchrotron radiation. One is the large energy loss limiting the beam energy practically up to 120 GeV. Another is the equilibrium state limiting the beam emittance, especially in horizontal direction. To obtain the better beam performance breaking the limits by the ring, Linac (Linear Accelerator) is revived. In linear collider, the beam is accelerated by linear accelerator. The beam orbit is in line and the synchrotron radiation is negligible. Linac based synchrotron radiation facility can realize short pulse and high coherent light. The linear accelerator is that accelerates the charged particle with periodic RF structures aligned in line. The beam geometry in the linear accelerator is independently determined from the lattice structure. Then, if one can generate the low emittance beam and can accelerate the beam without a significant emittance growth, an extremely low emittance beam can be obtained. That is also true for a short pulse beam. The electron source is one of the most important device in Linac, because the performance of the accelerated beam strongly depends on the initial beam quality. A photo-cathode is able to generate a high-performance electron beam with a large operability. The thesis addresses a couple of studies for the advanced photo-cathode.

One is substrate dependence of CsK_2Sb cathode which is the best cathode for high brightness electron beam at this moment. In this thesis, we studied a couple of subjects for the advanced CsK_2Sb photo-cathode was fabricated on several substrates as the test sample. GaAs(100), Si(100), and Si(111) were examined. We found that the cleaned substrates resulted in higher performance than the as-received substrates for all materials. By comparing cathodes on GaAs(100), Si(100), Si(111), and Mo, we found that the cathode on GaAs(100), Si(100), and Mo(100) had significantly better performance than that on Si(111) and Mo(amorphous). It showed that the cathode performance depends strongly not only on the substrate material and surface state, but also on the crystallinity and the surface direction. This is the first experimental evidence for substrate surface direction dependence of CsK_2Sb photo-cathode performance. The difference can be explained that the band structure of CsK_2Sb. The result suggests the importance of substrate choice on material, crystallinity and surface direction to optimize the cathode performance. This fact has an impact on the experimental physics with accelerators, because there is some potential to improve a thin-film cathode performance by revisiting the substrate crystallinity and surface direction of the substrate. The high QE has a large merit to generate a high brightness electron beam by relaxing requirements for the drive laser, etc. The fewer requirements for the laser make the system reliable, and stable. The availability of the system is improved and the effective cost of the project (cost per operation time) becomes less. Our result has a potential of the large impact on the accelerator science from this point of view.

The second is that understanding for the NEA surface. The NEA surface is a surface state in which the energy level of the vacuum is lower than the lowest level of the conduction band. The NEA surface is fragile and easily damaged by residual gas adsorption or beam extraction. At present, there are some hypotheses, but the structure of the NEA surface is not understood well. We studied the activation process of NEA surface with several gas(CO_2, CO, and N_2) species to improve our understanding for the NEA surface. In a nominal activation with O_2 gas, we found that the heights of each yo-yo peak are proportional to O_2 exposure. CO and N_2 did not activate the NEA GaAs cathode at all. CO_2 activated the NEA GaAs cathode, but the QE was 2.3% which was much lower than that with O_2. We found that the activation ability of O_2 molecule and atomic oxygen were $15.4\pm0.1L^{-1}$ and $7.7\pm0.1L^{-1}$, respectively. The low QE of the cathode activated with CO_2 can be explained with the degradation by CO to the NEA surface. The degradation ability of CO was estimated to be $0.91\pm0.09L^{-1}$, which is consistent to 0.84 by a preceding study. This effort is the first experiment to perform the NEA activation with CO_2 and the first measurement for the activation ability of O_2 and O, separately. Although these experimental facts provide useful information for better understanding of the NEA surface, it is still not sufficient. Establishing a robust NEA GaAs cathode is a future issue.