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IT-5-P-1792 Spatial and Temporal Coherences in Spin-Polarized Transmission Electron Microscopy

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Great advances have recently been made in magnetic recording technology and spintronic devices, which are promising for high-density storage devices. Such devices are expected to lead to the development of systems that can analyze magnetic and spin states with a nanometer-order spatial resolution.

We have commenced a development of a spin-polarized transmission electron microscope (SPTEM), which consists of a polarized electron source (PES) and a conventional TEM [1-3]. Figure 1 shows a photograph of the SP-TEM. Spin-polarized electrons can be generated using an optical orientation of III–V semiconductors and vacuum extraction that uses a negative electron affinity (NEA) surface. Several beam parameters of the PES are vastly superior to those of conventional thermal electron beams. In addition, it has the ability to generate a sub-picosecond multibunch beam[4]. A high ESP of 92% and a high QE of 0.5% have been realized using a GaAs–GaAsP strained superlattice photocathode[5].

We have already demonstrated that the SPTEM can provide both TEM images and the diffraction patterns [1]. The TEM images can be obtained in a spatial resolution of 1 nm in a 30-kV acceleration voltage. The apparatus has a below 240-meV energy width of electron beam in the TEM without any monochrometors (Fig. 2). The energy width indicates the temporal coherence is about 2.7 fs (longitudinal coherence of 2.7×10^{-7} m) at 30-keV beam energy. A brightness is directly measured by taking a spot size and a convergent angle on an image plane. The measured brightness is about 4×10^{7} A/cm^{2}sr in a 30-keV beam energy with a polarization of 82 % and the drive-laser power of 800 kW/cm^{2} on the photocathode [6]. The brightness for a 200-kV beam energy is 3×10^{8} A/cm^{2}sr which is converted by using a Lorentz factor. The order of the brightness is enough to do an interference experiment. We also demonstrated interference fringes of spin-polarized electron beam by using a newly installed biprism as shown in figure 3. These results indicate the SP-TEM can provide enough coherence in both lateral direction and longitudinal direction even if the semiconductor photocathode is used for an electron emitter.

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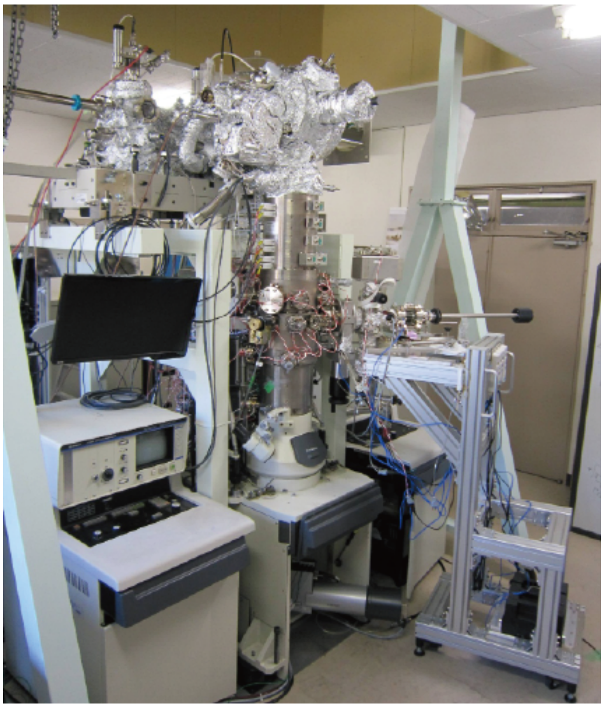

Fig. 1: Photograph of the spin-polarized TEM.

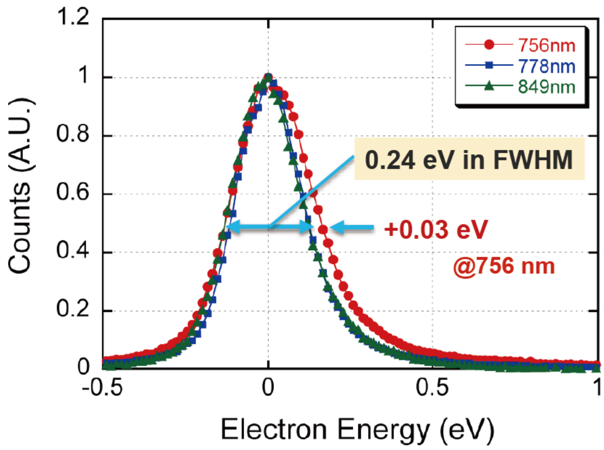

Fig. 2: Energy spread of spin-polarized electron beam as a function electron energy.

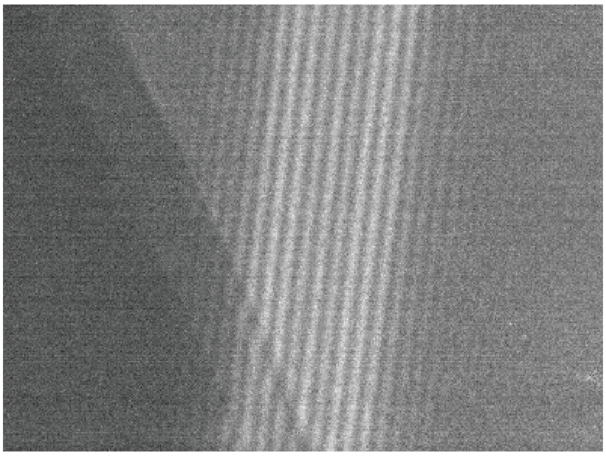

Fig. 3: Interference fringe of spin-polarized electron beam extracted from a GaAs-GaAsP strained superlattice photocathode using a biprism.