Nano-second Time-Resolved Measurement in Spin- Polarized Pulse TEM

Yoshito Nambo[1], Makoto Kuwahara [1], Soichiro Kusunoki [1], Kensuke Sameshima[1], Koh Saitoh[1,2], Toru Ujihara[1], Hidefumi Asano[1], Yoshikazu Takeda[1] and Nobuo Tanaka[1,2]

[1]Graduate school of Engineering, Nagoya University, Nagoya, 464-8603, Japan
[2]EcoTopia Science Institute, Nagoya University, Nagoya 464-8603, Japan

Investigations of ultra-high-speed physical phenomena in nanometer scale are important for developments of nano-devices. Furthermore, acquisition of a spin information such is necessary for densification of magnetic recordings and developments of spintronics devices. It is expected that spin-polarized transmission electron microscopy (SP-TEM) can clarify these topics.

Figure.1 shows the experimental equipment for a pulse TEM imaging. The SP-TEM consists of laser-driven polarized electron source (PES) and conventional TEM (Hitachi H-9000-UHV). The PES is configured with GaAs-GaAsP strained superlattice photocathode using a negative electron affinity (NEA) surface which has high polarization of 92% and high quantum efficiency of 0.5% [1]. Moreover, this photocathode also has an ability of generating a sub-ps pulsed electron beam [2]. Pulsed electron beam is emitted by illuminating a pulse laser to the photocathode. The pulse laser is generated by modulating a continuous wave (CW) laser using an acoustic optical modulator (AOM) which can control both the pulsewidth (~70ns) and repetition frequency ($\lesssim$ 10MHz). In addition, a time structure of the electron beam is directly measured by the Faraday-cup current monitor.

Figure.2 (a) and (b) show the TEM images obtained by using a continual electron beam and pulsed electron beam, respectively. The image of Fig.2 (a) is wobbled TEM image by using an alignment deflector coil. The wobbling amplitude is dramatically decreased by using a pulse beam as shown in Fig.2 (b) [3]. Fig.3 is a time structure of the pulse electron beam as a function of time. The data indicates a 70-ns pulse duration is obtained by the photocathode as same as the laser pulse duration which is the shortest pulsewidth created by the AOM. Moreover, the construction of optical setup for pump-probe method is also carried out. 1-ns pulse laser is separated two beam line by a polarized beam splitter. One of the beam line is delayed by passing a variable delay-line. The two separated beams are measured by a photo-detector simultaneously as shown in Fig.4.

From these results, measurements with a high temporal resolution can be carried out in the SP-TEM. It is expected that this instrument gives a possibility of investigations of spin dependent phenomena such as a time-evolution of photo-induced magnetism on nanometer scale.

References

[1] T. Nishitani et al., J. Appl. Phys. 97 (2005) 094907.
[2] Y. Honda et al., Jpn. J. Appl. Phys. 52 (2013) 086401.
[3] M. Kuwahara et al., Microscopy 62 (6) (2013) 607-614.

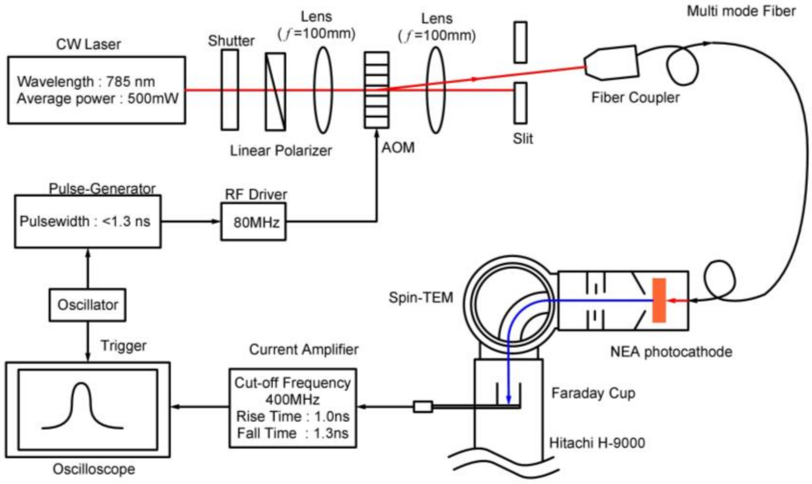

FIG. 1. Schematic diagram of a measurement system for the time structure of pulse beam by using a Faraday-cup current monitor in SP-TEM.

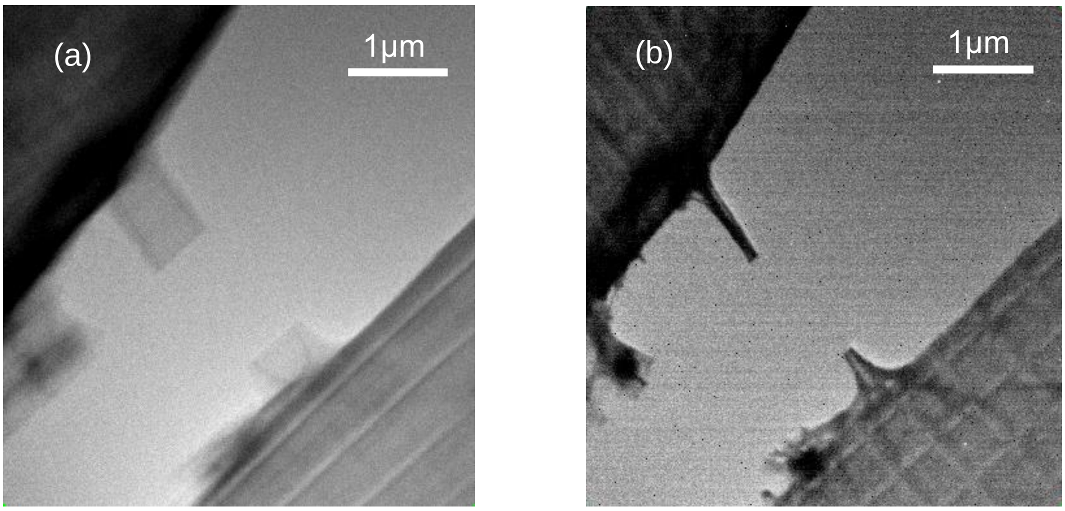

FIG. 2. Wobbling TEM images acquired by illuminating (a) continual electron beam and (b) pulsed one.

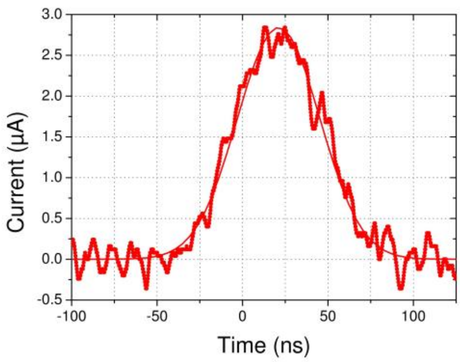

FIG. 3. A time structure of pulsed electron beam.

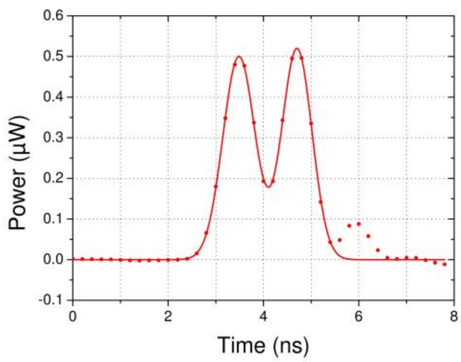

FIG. 4. A temporal structure of split two laser beams with a 1.5 ns delay-time.