Generation of intense terahertz surface waves on a metal wire by high-intensity laser driven electrons

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Abstract

In this thesis, the author summarizes the research on high-energy electrons and high-intensity terahertz surface waves generated by the interactions between high-intensity laser pulses and solid target.

The detailed studies of electron emission by laser-foil interactions let us know that electrons are emitted in surface direction for metal foil, while in laser direction for insulation foil. It has suggested us and been actually demonstrated that a metal wire target emits electrons in its direction and gives high directivity. For more detailed studies, we have proposed the configuration to separate electron guidance wire from laser accelerated electron source (foil). The demonstration has been successful. The aluminum foil is irradiated by a laser pulse at an intensity of 3.5×10^{19} W/cm^2, and accelerated electrons are guided in the direction of the tungsten wire, which does not contact the foil. It has been found that a metal wire has a function to improve the directivity of electrons emitted from a foil irradiated by an intense laser pulse. The electron guidance by a metal wire would be caused by transient electromagnetic fields formed on the wire surface or foil surface, but the detailed mechanism has not been elucidated. For the studies of intense laser plasma interaction and the development of terahertz wave source, the investigation of electromagnetic field around the laser plasma is also rather important. So, the characteristics of the surface wave induced in the wire are investigated.

We have investigated the spatial distribution and laser energy dependence of high-intensity terahertz surface waves generated from a metal wire irradiated by a high-

intensity laser pulse. A metal wire has a function as a terahertz waveguide. The terahertz wave propagates on the surface of the metal wire as a surface wave in a mode known as Sommerfeld mode. We have measured the electric and magnetic fields of surface waves by electro-optic and magneto-optic effects, respectively. When the laser intensity was 2.9×10^{19} W/cm^2, the peak electric field of the surface wave induced on the surface of the copper wire with a diameter of 300 μm is estimated to be 1.8 MV/cm on the wire surface. The peak electric field of the surface wave tends to increase with increasing laser energy. Experimental results show that the energy conversion efficiency from laser to surface wave is proportional to the 0.3th power of laser energy. The direct measurement of the THz wave magnetic field by MO effect has been also performed. The observed magnetic field is about 0.8 T at the maximum, and almost coincided with the electric field measurement result.

We have demonstrated that a terahertz surface wave with 110 kV/cm field strength can be induced on a metal wire by the interaction of an intense femtosecond laser pule with an adjacent metal foil at a laser intensity of 8.5×10^{18} W/cm^2. The polarity of the electric field of this surface wave is opposite to that obtained by the direct interaction of the laser with the wire. Numerical simulations suggest that an electromagnetic wave associated with electron emission from the foil induces the surface wave. A tungsten wire is placed normal to an aluminum foil with a gap so that the wire is not irradiated and damaged by the laser pulse, thus making it possible to generate surface waves on the wire repeatedly.