Terahertz-wave generation from atomic clusters under the irradiation of intense femtosecond laser pulses

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Abstract

Terahertz (THz) electromagnetic waves generated in the interaction of an intense femtosecond laser pulse with argon clusters have been investigated. To understand the physical mechanism of THz-wave generation and to improve the properties of THz radiation, the properties of THz waves, such as angular distribution, laser energy dependence, spectrum, and polarization, have been investigated experimentally.

By irradiation of a single-pulse beam with various pulse duration, THz waves show the strong relationship between THz wave intensity and laser pulse duration. The energy of THz waves reaches a peak at a pulse duration of ~250 fs, where it is ~4 times higher than the THz energy at ~40 fs. The controlling plasma density increases the laser absorption of clusters, resulting in increasing emitted electrons which would attribute to THz-wave generation. However, irrespective of pulse duration of the incident laser, the radially polarized THz waves radiate with conical angular distribution. The main mechanism of THz-wave generation would be the quadrupole radiation which is induced by ponderomotive force.

While optimizing laser pulse duration enhances the THz-wave energy, the polarization and angular distribution should not be appropriate to applications. By irradiation of noncollinear double-pulse beams, THz waves generated from cluster plasma have been much improved: high forward directivity, power enhancement, and linear polarization with variable direction. These characteristics are useful for applications because they result in highly efficient use, higher power, and variable polarization, respectively. Irradiating argon clusters with double pulses in 133-ps and 40-μm intervals

results in terahertz wave emission in the forward direction that is 10 times greater than that for a single pulse.

The properties of THz waves for noncollinear double-pulse beams experiments are different from that for conventional schemes using single-pulse beam. As a mechanism of THz-wave generation in the interactions between argon clusters and noncollinear double-pulse beams, dipole radiation as with the scheme using an artificial DC field for a plasma channel. By Coulomb-expansion induced by first pulse, ions are emitted to form expanding (positively charged) ion clouds which might work as a DC field for plasma channel produced by second pulse.

These research progress should be significant and useful for the further understanding and applications of THz wave generation via an interaction between femtosecond laser pulses and atomic clusters.