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Design of Gridless Ion Mirror for Time Focusing by Energies of Ions in Laser Ion Source

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Abstract

Possibilities of gridless ion mirror usage in conjunction with laser ion source were studied in this paper. This was done in order to get time focusing by energies of ions. Mirror voltages were adjusted so that time focusing by energies of 6th was achieved. This means reduction of time aberrations down to 1 ns. Such a time focusing can be applied to ions with energy spread up to ±20%.

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1. Introduction

Two main physical problems in laser mass spectrometry are high plasma density and large energy spread of ions extracted from plasma. To solve these problems, researchers are creating a long free plasma drift gap and trying to reduce the energy spread of ions [1, 2, 3]. For example, when using an energy window which lets ions of energy range of ± 1% pass to a detector, given average initial ion energy W_0=50 eV and accelerating voltage V_0=1000 eV (average ion energy is equal to 1050 eV), ions arriving to the detector will have initial energies in the range of 39.5 - 60.5 eV. Further increase in the resolving power is limited due to time aberrations of the 2nd order, arising in the

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drift space, that reach quite high values [4].

In [1, 2] to solve these problems a collision cell with a buffer gas is set in the source. As the result, ions reduce their energy spread and formation of ion packages are performed using an orthogonal input into mass-reflectron analyzer.

2. The method principle

In this letter authors propose another approach to the formation of ultrashort ion package with the help of a laser ion source. The configuration of the ion source for one embodiment of the idea of such focusing is shown at Fig. 1a.Laser plasma cloud is generated as result of irradiation of analyzing sample with a laser operating in Q-switching mode. Focusing optical lens FL creates focal spot of diameter d_f=30-50 microns. Power density is q~(3-5) 10^9 Wt/cm^2. Created laser plasma expands almost with a constant velocity [4] because of its own not compensated space charge after ultrashort phase of its freezing (1-3 ns). After weakening it by a skimmer S and a slit, laser cloud enters the area where it is shattered by the magnetic field, but formed narrow ion beam is directed in a gridless ion mirror/reflector [7]. The reflector is adjusted so that it makes ion beam, leaving it, parallel. This is needed for correction of time aberrations by radial divergence angles of the 2nd order [6] in the analyzer, which is used as telescopic mirror.

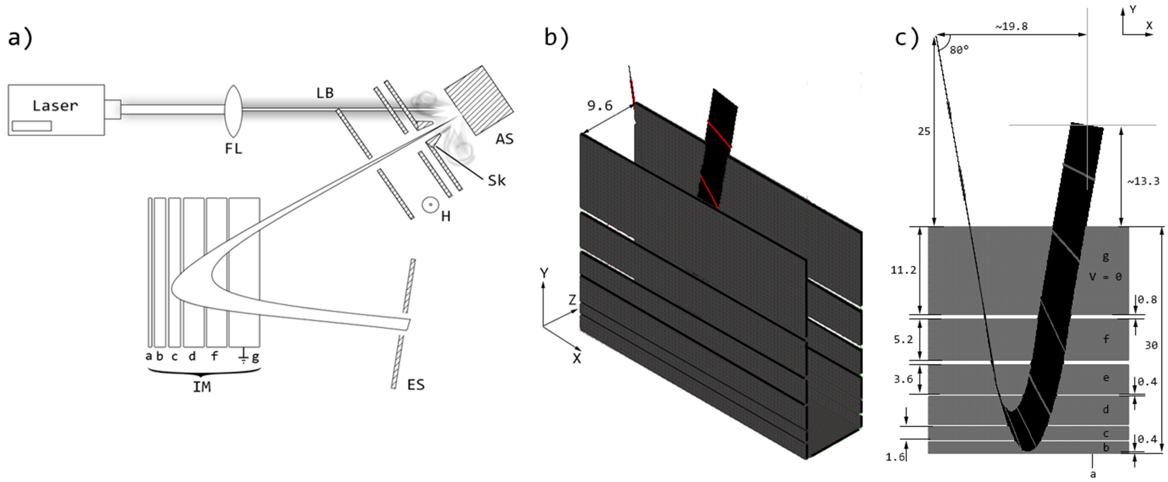

Fig. 1 (a) Ion optics scheme of laser ion source providing time focus. LB – laser beam, AS – sample, Sk – skimmer, IM – ion mirror, FL – focusing lens, ES – exiting slit, H – magnetic field vector. (b) Gridless ion mirror design. Isometric projection. (c) Gridless ion mirror design. XY projection. Letters a – g represent plate pairs.

The studies were conducted by modeling the selected configuration of ion source with help of the software package SIMION 8-3D [8]. In [7] it was shown that the use of gridless ion mirror allows one to get a time focus of the 4th and 5th order in ion energy. Furthermore, absence of nets can reduce losses of ions in the source. Ion mirror comprises six pairs of parallel plates and a reflecting plate (Fig. 1b,c). Plates voltages are set with a single power supply and two voltage dividers. Dimensions of the device are given in mm. Light lines that cross trajectories of ions represent time markers at interval of Δt ~ 0.8 us.

Ions move in XZ plane, and are focused due to inhomogeneity of the electric field created by the plates. The plates have different Y sizes in order to set the field more precisely. Used in this study mirror differs from that in [7] by geometric proportions and by being smaller. To speed up the search, 11 ions within range of initial energies - 39.5 - 60.5 eV were generated. Ions had mass of M = 64 amu. Ions entered the mirror at an angle of 10°. Optimal voltages for the plates were found by a genetic algorithm [9], implemented as LUA script for SIMION 8-3D. Found voltages are shown in Table 1.