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加速器学会

FROL10

レーザー駆動陽子加速のための水素クラスターターゲットの特性評価

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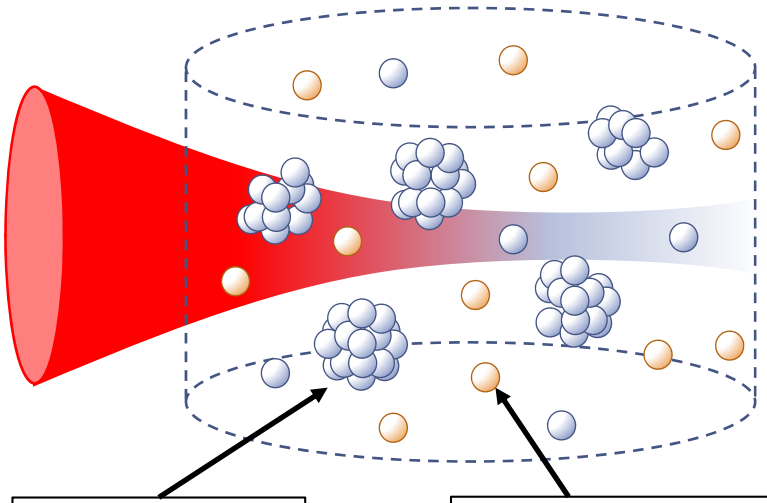
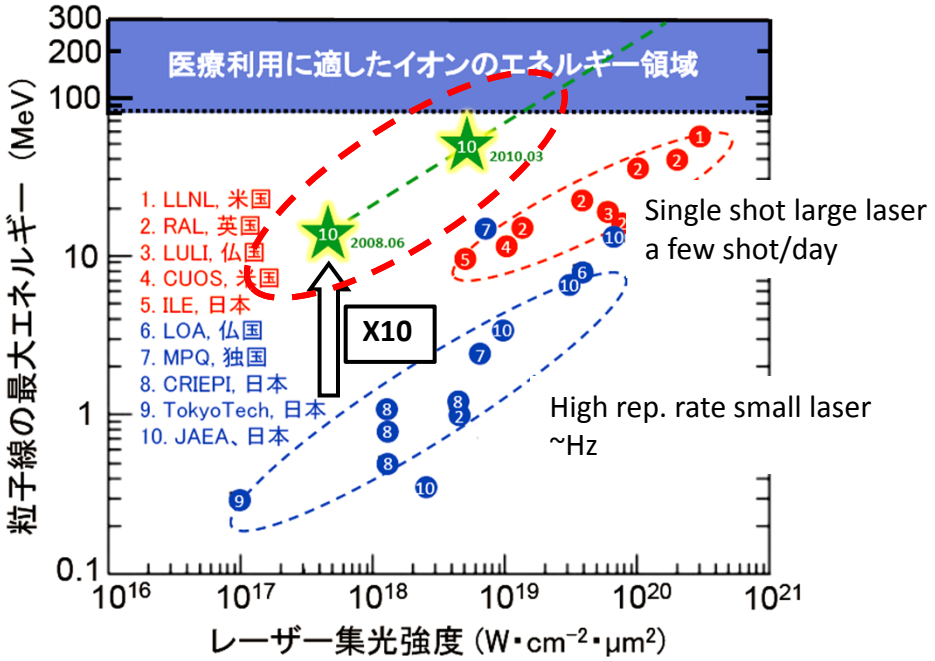
Laser driven ion acceleration using cluster targets

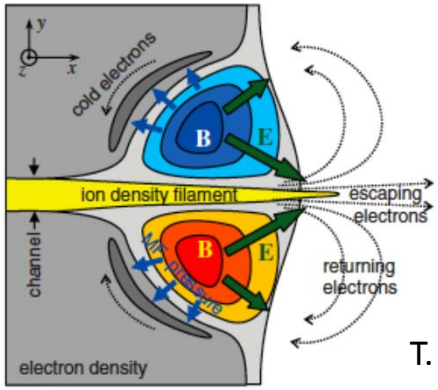
10^{17} - 10^{19} W/cm^2





Y. Fukuda *et al.*, Phys. Rev. Lett. **103**, 165002 (2009)
Y. Fukuda, S. Jinno *et al.*, Radiat. Meas. **50**, 92 (2013)

Magnetic-field assisted ion acceleration



T. Nakamura, et al., Phys. Rev. Lett. 105, 135002 (2010)

Tenfold enhancement of acceleration ion energy

Coulomb explosion of clusters

K. Nishihara, *et al.*, Nucl. Instrum. Meth. A **464** (2001) 98–102.

Maximum ion energy obtainable from "pure" Coulomb explosion:

$$E_{\max} = 300 Z^2 \times \left(\frac{n_0}{5\times10^{22}\,\mathrm{cm}^{-3}} \right) \left(\frac{R_0}{1\mu\mathrm{m}} \right)^2 = 276 Z^2 \times R_0^2(\mu\mathrm{m})\,\mathrm{MeV}$$

Ex) H_2 cluster

44 MeV (dia. 800 nm) <= good to trigger nuclear reaction

276 MeV (dia. 2000 nm) <= good for cancer therapy

Laser intensity required to <u>remove all electrons</u> from a cluster:

$$a_0 = 34\sqrt{2} \times \sqrt{\frac{4.6\times10^{22}\,\mathrm{cm}^{-3}}{5\times10^{22}\,\mathrm{cm}^{-3}}} \left(\frac{R_0}{1\mu\mathrm{m}} \right) = 46.11 \times R_0(\mu\mathrm{m})$$

Ex) H_2 cluster

7×10^{20} W/cm^2 (dia. 800 nm) <= good to trigger nuclear reaction

4×10^{21} W/cm^2 (dia. 2000 nm) <= good for cancer therapy

The “J-KAREN” : Intense Laser Facility at JAEA-KPSI

Under a major upgrading

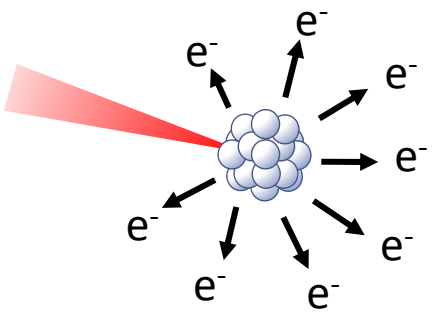
1 PW mode (40 J, 30 fs, 0.1 Hz) coming soon…

10^{21} - 10^{22} W/cm^2

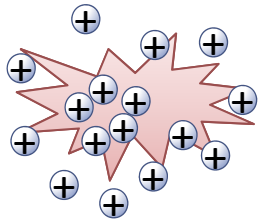
H. Kiriyama et al., Opt. Lett. **37**, 3363 (2012).

Submicron size H_2 cluster

Maximum energy
by Coulomb explosion:



44 MeV (dia. 800 nm)



Coulomb explosion

In the recent simulation study, it is expected that
the protons have the directionality.

Y. Fukuda, R. Matsui, Y. Kishimoto *et al.,* 15th APRS, Kyoto, (2014).

Purpose

Formation of hydrogen cluster

Small van der Waals' force

Cooling the pulse valve

Pulse valve cooled by the liquid helium

Previous study

Liquid nitrogen cooling

Cluster size ～10 nm

T. Ditmire, et al., Phys. Rev. Lett. 78, 3121 (1997)
S. Sakabe, *et al.*, Phys. Rev. A 69, 023203 (2004)

Coulomb explosion: about 10 keV

Theoretical prediction of the hydrogen cluster size distribution is difficult.

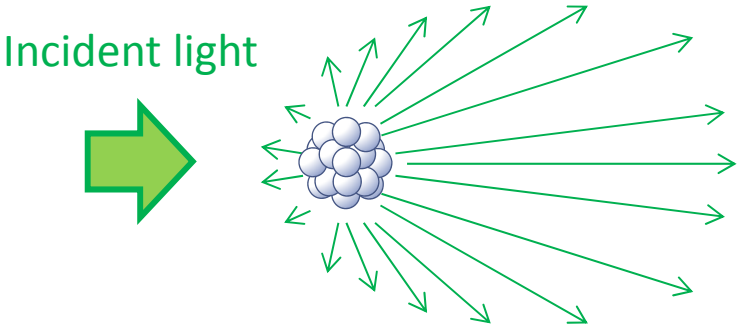
Target diagnosis

Size measurement using Mie scattering

- Investigation of the cluster formation condition
- Development of the formation model

Measurement principle of particle size

Applicable size: 0.1 μm ~ 10 μm
(For the size greater than wavelength order)



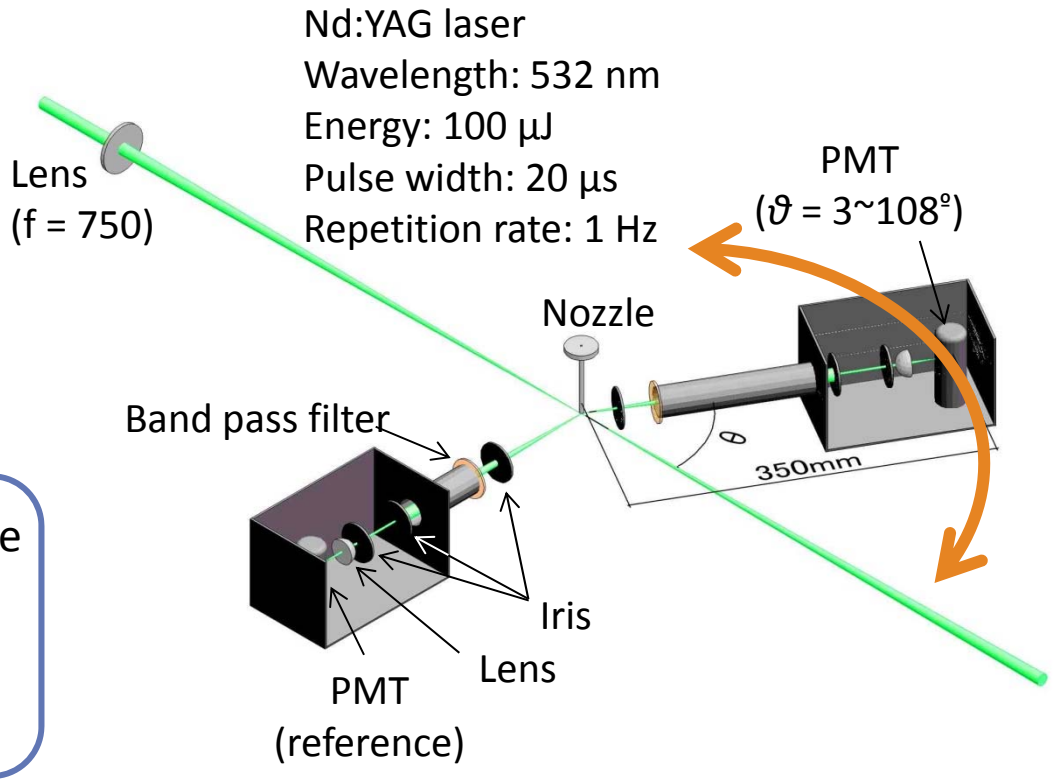
Mie scattering

Forward scattering increases with the size

Need to consider the anisotropy

Measurement of scattering angle distribution to size evaluation

Apparatus for measuring cluster size



Specification

Vacuum: ~10^{-6} Pa
Measurement time: 30 sec./1 plot
Angular resolution: 0.5 deg.

Size analysis algorithm

Size distribution

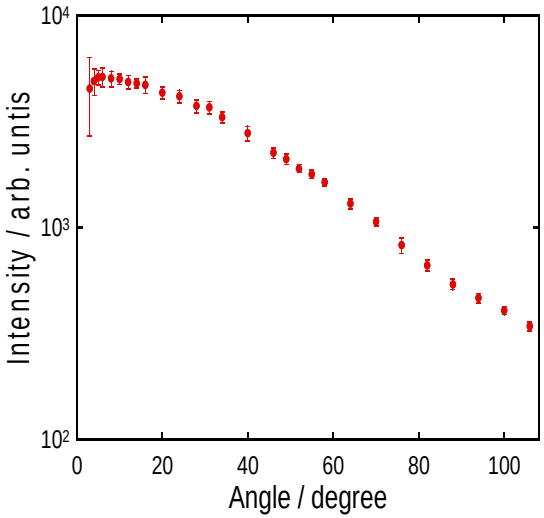
$$I(\theta) = \sum_x f(\theta, x) n(x)$$

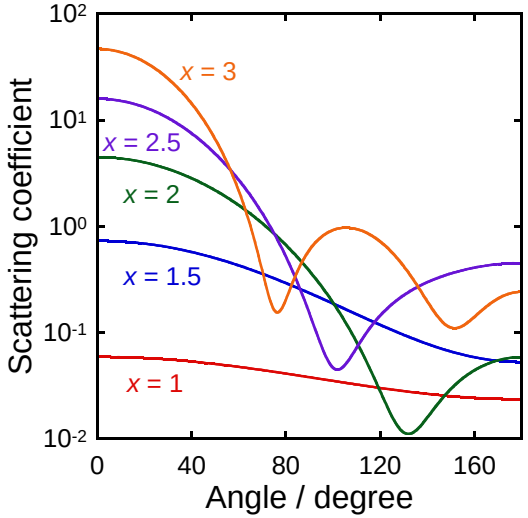
Solve the inverse problem

$$n(x) = \sum_\theta [f(\theta, x)]^{-1} I(\theta)$$

Angular distribution obtained from experiments

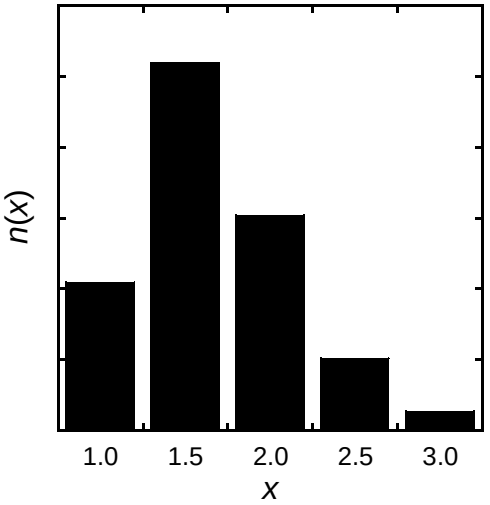
Scattering coefficient for each size by Mie theory





- Non-negative least square method
- Phillips-Twomey method (to obtain a smooth solution)

Size distribution: $n(x)$



Summary

- Development of submicron-size H_2 clusters
  - ✓ Constructed the nozzle with the cryostat

- PIC simulation for H_2 clusters @ 10^{22} W/cm^2
  - ✓ Several tens MeV "*impurity free*" protons from PW lasers