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Material dependence of laser accelerated electrons temperatures
レーザー加速された電子の温度の材料依存性

Yousuke Mishima[1)], Hideaki Habara[1)], Yasuhiko Sentoku[2)], Tomoyuki Iwawaki[1)], Kenshiro Kikuyama[1)], Takuya Kouno[1)], Tomoya Morioka[1)], Kiyoshi Morita[1)], Mamiko Nishiuchi[3)], Akifumi Yogo[3)], Alexander Pirozhkov[3)], Yuji Fukuda[3)], Koichi Ogura[3)], Tuyoshi Tanimoto[3)], Kiminori Kondo[3)] and Kazuo Tanaka[1)]

三島陽介[1)], 羽原英明[1)], 千徳靖彦[2)], 岩脇智行[1)], 木久山健志郎[1)], 河野卓也[1)], 森岡朋也[1)], 森田清[1)], 西内満美子[3)], 余語覚文[3)], Alexander Pirozhkov[3)], 福田佑仁[3)], 小倉浩一[3)], 谷本壮[3)], 近藤公伯[3)], 田中和夫[1)]

1) Graduate School of Engineering, Osaka University, 2-1 Yamada-oka, Suita, Osaka 565-0871, Japan
大阪大学大学院工学研究科電気電子情報工学専攻　〒565-0871　吹田市山田丘2-1
2) Physics Department, MS-220, University of Nevada, Reno, Nevada 89557, USA
ネバダ大学リノ校物理学部　89557
3) Advanced Photon Research Center, Japan Atomic Energy Agency, Kidugawa 619-0215, Umemidai, Kyoto 8-1-7Japan
日本原子力研究開発機構関西光科学研究所　〒619-0215　木津川市梅美台8-1-7

We have investigated that the material dependence of electron acceleration by ultra-intense laser light. Recent particle simulation shows that the average energy of fast electron decreases from the prediction of ponderomotive scaling if the intense laser light directly interacts with solid material when the laser has a high pulse contrast or long pulse duration enough to sweep out preplasma. Experiments have been performed by using J-KAREN laser system (10^{20}W/cm^2, 50fs, 10^9 contrast). In the result, the electron energy from Al target is about 40% larger than that from Au. This ratio well agrees with the ionization degree from the calculation in the actual laser parameters, resulting that strong dependence of number of free electrons on the electron acceleration.

1. Introduction

In fast ignition of inertial fusion research, control of input fast electron energy is important to heat the implosion plasma core efficiently because low energy electrons scatters in long scale corona plasma and high energy ones pass the core plasma without depositing their energy. The most efficient energy range of electron slope temperature is thought about 1 MeV [1].

Recently Chrisman *et al*. provided the new model, which hot electron temperature ε_h decreases by $n_s^{1/2}$ as increasing electron density n_s of target material as described below equation [2],

$$\varepsilon_h = m_e c^2(\gamma_{os} - 1)\sqrt{\gamma_{os} n_c / n_s} \qquad (1)$$

where m_e is electron mass, c is the light velocity, γ_{os} is the electron's relativistic factor, n_c is the critical density, and n_s is solid electron density. Actually their PIC simulation result is showing that $n_s^{1/2}$ dependence of electron slope temperature. If laser system have high contrast ratio or pulse duration enough to sweep out preplasma, the intense laser can interact with solid electron density directly. Hot electron temperature accelerated by J×B model at critical density plasma is generally characterized by Ponderomotive-Scaling [3], but electron temperature is said to get lower value than the scaling if the laser interacts with target directly. If assuming equation (1) is valid in direct interaction condition, lower atomic number material should get higher electron temperature than that of higher one when laser energy is transported to fast electrons averagely. In this letter, we have performed the experiment to see whether material dependence of electron temperature exit or not.

2. Experimental Setup

We have performed the experiment by using J-KAREN laser system, Advanced Photon Research Center. The experimental set up is shown in Fig. 1. Laser intensity is ranging from 10^{19} to 10^{20} W/cm^2 with 50fs pulse duration, 2~20J energy, 800nm

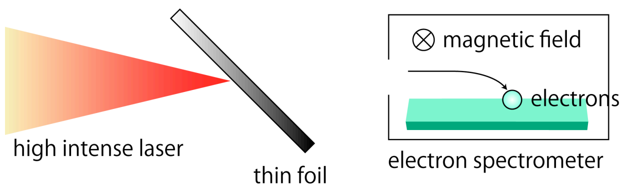

Fig. 1. Experimental Setup

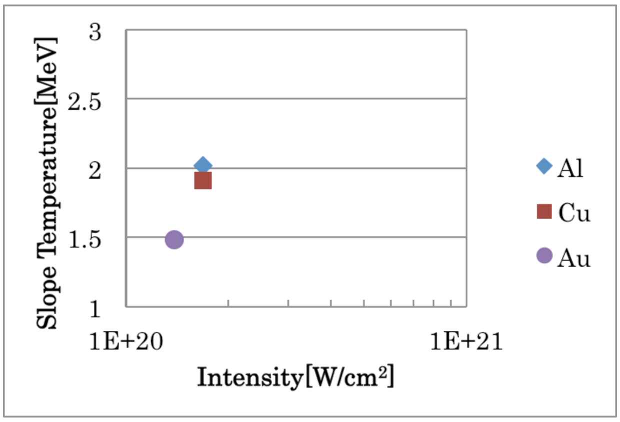

Fig. 2. Electron slope temperature against laser focal intensity

wavelength and P polarization axis. Incident angle was 45° and electron spectrometer (ESM) was installed along the laser axis. Several targets were used, Al, Cu and Au with thickness of 2, 10, 2.5μm respectively.

3. Result

Laser intensity dependence of electron slope temperatures for each material are shown in Fig. 2. Au got slightly lower slope temperature than that of Al. But the electron energy of Al target is about only 40% larger than that from Au, though the atomic number of Al is one-sixth as large as that of Au. So if substituting $n_s = Zn_i$ into equation (1), which Z is valence number and n_i is ion density, ionization degree of each material can be estimated by comparing two results. Ionization degree can be described as below equation,

$$Z_{Au\,or\,Cu} = \frac{Z_{Al} n_{i,Al}}{n_{i,\,Au\,or\,Cu}} \left(\frac{T_{Al}}{T_{Au\,or\,Cu}} \right)^2 \frac{I_{Al}\gamma_{Al}}{I_{Au\,or\,Cu}\gamma_{Au\,or\,Cu}} \qquad (2)$$

Assuming Al is fully ionized, the ionization

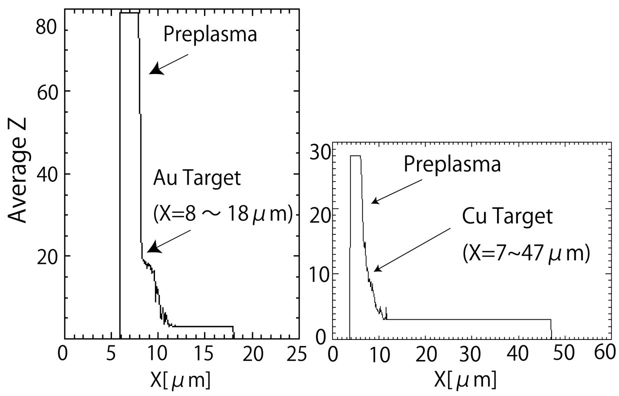

Fig. 3. Average ionization degree Z on Au and Cu: fully ionized preplasma exist in front of target

Table 1. Ionization degree comparison between Experiment and PIC simulation

	Al	Au	Cu
Experiment	13	18.5	10.4
Simulation	-	21	12

degree of Cu and Au are estimated as 10.4 and 18.5 respectively. Why the ionization degree of Cu got lower than that of Al can be explained that the ion density of Cu is 1.4 times higher than that of Al one. Next, PICLS code [2][4][5], including field and collisional ionization processes (Thomas-Fermi model) and fully relativistic energy conserving binary collision model, has been utilized to estimate ionization degrees. In this simulation, laser intensity is 5×10^{19}W/cm^2 with pulse duration is 50fs (constant intensity after Gaussian rising) and P polarization is used. The used thickness of Au and Cu are 10μm and 40μm respectively. The result of average ionization degree estimation is shown in Fig. 3. Note that fully ionized preplasma is located in front of the target surface. The ionization degree results of simulation and experiment are organized in Table1 and it is showing little difference between the two cases. It might be thought that ionization of Au gets higher value if more laser energy is injected.

4. Conclusion

If high intensity laser has high contrast ratio or long pulse duration enough to sweep out preplasma, the laser can interact with solid material directly and the scaling of J×B accelerated electron slope temperature is modified as equation (1). In the experiment conducted by J-KAREN laser, Au got slightly lower temperature than that of Al. The ionization degree of Au and Al in experiment and PIC simulation shows almost same results. Due to the results, the small ratio of slope temperature between Al and Au can be considered valid and higher ionization value of Au need much more laser energy.

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