Dynamics expansion of laser produced plasma with different materials in magnetic field

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Abstract. The dynamics expansion of the plasma generated by laser ablation of different materials has been investigated. The dynamics and confinement of laser generated plasma plumes are expanding across variable magnetic fields. A Q-switched neodymium-doped yttrium aluminum garnet laser with 1064 nm, 8 ns pulse width and 0.125 J laser energy was used to generate plasma that was allowed to expand across variable magnetic within 0.1 – 0.8 T. The expansions of laser-produced plasma of different materials are characterized by using constant laser power. CCD video camera was used to visualize and record the activities in the focal region. The plasma plume length, width and area were measured by using Matrox Inpector 2.1 and video Test 0.5 software. Spectrums of plasma beam from different materials are studied via spectrometer. The results show that the plasma generated by aluminum target is the largest than Brass and copper. The optical radiation from laser generated plasma beam spectrums are obtained in the range of UV to visible light.

1. Introduction
The use of a magnetic field with a laser-created plume is especially intriguing, as the magnetic field can be used to help control the dynamic properties of these transient and energetic plasmas. The collimation and stability properties of plasma flows across magnetic field are of particular relevance to the propagation of charged particle beams, bipolar flows associated with young stellar objects, solar wind evolution, and astrophysical jets etc. [1-2]. In the field of inertial fusion, confinement of expanding target plasma using a magnetic field offers a potential means to slow high-energy particles before they implant in surrounding structures. The presence of magnetic field during the expansion of laser produced plasma may initiate several interesting physical phenomena [3-12], including conversion of plasma thermal energy into kinetic energy, plume confinement, ion acceleration, emission enhancement, plasma instabilities, etc.

Pulsed laser induced plasma has very short temporal existence and transient in its nature, with a fast evolution of the characteristic parameters that heavily dependent on irradiation conditions such as incident laser intensity, irradiation spot size, ambient gas composition and pressure. It is also true that these parameters vary drastically with axial or radial distance from the target surface under the same irradiation conditions [13]. In present work high-speed imaging technique is used to grab the image of plasma plume expansion. The production and expansion of plasma in magnetic field, obtained by irradiating Al, Cu and brass targets with a pulsed Nd:YAG laser are investigated and plasma beam spectrum are also discussed.
2. Experimental setup
Focused pulses from Nd:YAG laser (1064 nm, 8 ns and 10 Hz) were used to create copper, aluminum and brass plasma in variable magnetic fields in free space. The target material is placed ~1 cm at the pole edges. The separation between the two poles was kept constant distance at a of 1.5 cm. Uniform magnetic field was produced vertically with respect to the incoming beam and could be verified in the range of 0.1 T – 0.8 T while the laser energy is kept constant as 125 mJ. It means that the IR laser was focused perpendicular to the magnetic field. The activities at the focal region were visualized by using CCD camera. The optical radiation from the plasma region was analyzed by using Ophir Wave Star spectrometer interfaced with personal computer.

3. Results and Discussions
When IR laser was focused on target by using lens of 200 mm focal length in variable magnetic fields, plasma was generated on the target surface at atmospheric pressure in room temperature. The expansion of plasma formation was studied via changing the magnetic field. Two-dimensional images of laser-produced plasma provide an orthogonal view of the expansion with respect to the target plane. Typical CCD images of the expanding plasma plume on target sequenced in the presence of variable magnetic fields recorded after the breakdown are shown in Figure 1.

Two types of plasma shape are observed from the images of Figure 1. First, the plasma is expanding horizontally to the laser beam axis and secondly, plasma is expanded vertical to the laser beam. The horizontal plasma expansion is not due to energy of laser delivered to focal region (as laser energy is constant) but it is due to the force of motion or any related physical phenomenon subjected to be due to the magnetic field. Initially the hemispherical plasma was formed with respect to the target surface. As the magnetic field increases, the plasma is expanded elongated towards the incoming beam. The vertically expanding plasma is due to the motion of charged particles inhibited by magnetic field, which are forced, to spiral around field lines. Consequently, some of the charged particles move along the field lines and the Lorentz force that accelerated the charges to move faster and further away from the target. This means the magnetic field can impose plasma structure. As a result, we observed that some parts of the plasma expand in vertical position. Expansion also depends on the target material. It was observed that Al plasma has larger size than Cu and brass. The size of plasma was measured in horizontal and vertical expansion as illustrated in Figure 2. Both curves in Figure 2a and 2b indicate that the area of the plasma gradually increases with the magnetic field. Vertical plasma is found greater than horizontal plasma, which is in contrast with the plasma formation without magnetic field. However the magnetic field used in this expansion is not strong enough to totally change the structure of plasma.

Figure 1: Plasma Plume Expansion with Al, Cu and Brass respectively in variable magnetic fields. Magnification factor x 10.
Beside size of plasma plume, the plasma interaction with Al, Cu and Brass was also observed via spectrum analyzer. Ablations of different target materials create an intensely luminous plume that expands normal to the target surface. The typical spectrum produced due to plasma interaction with Al, Cu and brass is shown in Figure 3.

In Figure 3 the line spectrum of Al, brass and Cu plasma are produced in the range of 360 to 600 nm, 400 to 544 nm and 416 to 576 nm respectively. These intensities are corresponding to the high ionization level for each material. The highest emission lines of Al have photons energy in the range of 8.38 eV and 8.35 eV where as the lowest emission line comprise of 6.61 eV and 5.82 eV respectively. In contrast brass plasma; the photons energy of high emission lines are smaller that are 6.87 eV and 6.34 eV rather than lower emission line of 7.74 eV and 7.33 eV respectively. Similarly for Cu plasma, the photons energy of highest optical radiation is 6.41 eV and 6.34 eV while the lower line have 7.74 eV and 7.11 eV respectively. In general, the different plasma radiation produced spectrum in the range of ultraviolet to visible light. In case of Al plasma majority of emission UV light and minority with visible light dominate lines. Entirely different with copper and brass plasma; majority of the optical radiation comprise of visible spectrum that are in green light and minority of shorter wavelength that UV. The environment condition including the existence of molecules or particles, room temperature and pressure responsible to cool and confines the plasma plume, which enhance collision and excitation in Al target. The emission with larger wavelength is decreasing in intensity.
4. Conclusion
When a Q-switched Nd:YAG laser was focused on different targets like Al, Cu and brass targets, plasma was generated. The dynamic expansion of plasma was studied based on variable magnetic fields. The plasma was expanded in two ways that are in vertically and horizontally. Each expansion is due to the motion of charge inline with field and the Lorentz force that accelerated the charges to move faster and further away from the target. Both expansions are found gradually increases with the magnetic field. The luminosity of the plasma plume created the spectrum in the range of UV to visible with majority of beams is in UV region (bluish).

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