Characterization of Laser-Induced Plasmas Of Organic Compounds by spatially- and temporally resolved optical emission spectrometry

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MOTIVATION
The large majority of laser-induced plasmas experiments are performed in air at atmospheric pressure. Under this condition, the interpretation of the molecular emission of species containing C, N, O or H becomes difficult since their origin is unclear: are they directly released from native bonds contained within the sample's chemical structure? Or, on the other hand, are they formed due to recombination with the ambient constituents? Answering these questions may be of crucial importance in order to determine if the targeted molecular information gets lost in the course of the secondary reactions that occur in laser-produced plasmas. Considering that the spectrum observed is always a convolution of primary and secondary processes, experiments in vacuum may help to address such questions.

The present work shows detailed experiments where spatially-resolved optical emission spectroscopy of laser-produced plasmas has been performed on graphite with a focus on the evolution of the CN and C2 molecular bands under different pressure conditions. A comparison between the results obtained by using a nanosecond pulsed laser and a femtosecond pulsed laser as the excitation source is also drawn since the morphological differences of the plasmas may pose substantial alterations in the observed evolution of the two species.

EXPERIMENTAL APPROACH
The sample was placed inside a vacuum chamber where a range of pressures from 1000 mbar to 10^-3 mbar could be covered. For the excitation, 800 nm laser pulses at 35 fs were used along 1064 nm laser pulses at 4 ns. Both of the lasers were used with a fluence value of 3.1 J/cm^2. The laser-produced plasmas were focused into a spectrograph.

The CN molecular bands are a consequence of the recombination between graphite-emitted carbon atoms and the nitrogen present in the air. The plasma's expansion favours the possible interactions of the C and the N atoms hence the increase of the intensity observed for this band at moderate vacuum values. At higher values, the absence of nitrogen becomes so critical that the formation of these molecules is impeded.

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MORPHOLOGICAL CHANGES IN THE LASER-PRODUCED PLASMA AT DIFFERENT PRESSURE VALUES
A notorious change can be seen in the form of the plasmas between the ns-produced plasma and the fs-produced plasma; in the former, a radial expansion is observed while in the latter, the expansion is produced in the same axis as the laser incidence.

As the pressure is reduced, the density of the surrounding atmospheres is also decreased thus allowing the plasmas to expand greatly.

SPATIALLY-RESOLVED EVOLUTION OF THE TARGET SPECIES
C2 molecular bands are native to graphite since C2 molecules are directly released from the material. Their intensity is not directly affected by the vacuum values but by the distribution of the C2 molecules within the plasma instead, which becomes wider at higher expansion values of the plume. This fact might be supported by the shift in the intensity maximum that can be observed in the graphics.

Also, as can be seen in the graphics, while the bands become extinct, there are sudden increases in the intensity which may be explained by the recombination of previously broken C2 molecules.

CONCLUSIONS
- In spite of the substantial differences between the femtosecond laser-produced plasma and the nanosecond laser-produced plasma, no noticeable changes are observed in the tendency of the studied molecular species.
- The pressure does not only affect the morphology of the plasmas but also the measured intensity of the bands.

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