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**CARS TEMPERATURE MEASUREMENTS IN A PLASMA HEATED COAL COMBUSTOR**

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INTRODUCTION

Electricité de France which actively takes part in the characterization and the development of plasma generators, has equiped its research center at "Les Renardières" with a 2 MW plasma generator and a wind tunnel where a cold air flow is mixed with the plasma and where coal powder can be injected.

The foremost study is the heating of blast furnace injected gases. The purpose is to decrease the coke consumption by electrical heating of blast furnace winds, and burning coal powder in the plasma heated gas in place of a significant amount of coke.

In order to improve the plasma generators setup on blast furnaces it is necessary to achieve a two-dimensional temperature cartography in different sections of the wind tunnel including inside the plasma flare. Thus the aim is twofold:

- numerical models validation,
- coal combustion characterization and improvement.

The Coherent Anti-Stokes Raman Scattering (CARS) technique has been selected as one of the recognized technique for providing remote in-situ, non perturbing, temperature measurements with good spatial and temporal resolution [1-2-3].

Many cross-sections were scanned for different plasma torch operating conditions [Fig. 1], without coal combustion. Corresponding isotherms have been drawn and the results will be discussed elsewhere. This paper describes the multiplex CARS measurements in a plasma heated air flow seeded with coal powder, and emphasizes the encountered difficulties to correctly restore the local temperature [4].

**OPTICAL METROLOGY ON THE PLASMA TORCH  
(VELOCITY , TEMPERATURE)**

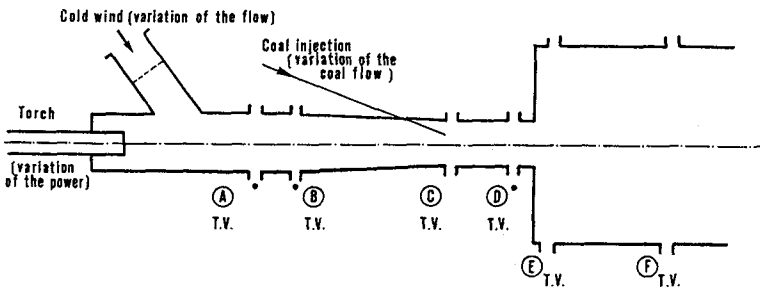


FIGURE 1

CARS FACILITY

The laser source is a commercial bench (SOPRA) where the pump laser  $W_L$  is a TEM<sub>00</sub> single mode, frequency doubled Nd<sup>3+</sup>: YAG with two amplifier stages. The Stokes laser  $W_S$  is a broadband dye laser, with  $W_L - W_S$  tuned on a vibrational Raman resonance of N<sub>2</sub> molecule. The beams are set in BOXCARS beam configuration for good spatial resolution (5 mm). The performances of the lasers are summarized in table 1.4

TABLE 1

	Wavelength	Pulse energy	Pulse duration	Rep. rate
$W_L$	532 nm	150 mJ	17 ns	5 Hz
$W_S$	606.3-608.3 nm	10 mJ	17 ns	5 Hz

The light routine requires 20 mirrors to maintain a critical alignment over a very long path (20 m) and with the mechanical X-Y displacements of focusing and recollimating lenses (cross section scanning) (Fig. 2).

The signal wave  $W_A$  is sent into a grating spectroscop (2100 lines/mm) and then recorded by an intensified multichannel detector EGG 1454 (512 diodes, 1 count for 40 photons). The detector is controlled by an optical multichannel analyser (EGG-OMA III) where the single shot multiplex spectra are stored prior to the transfer to an HP 1000 processing computer [Fig. 3].

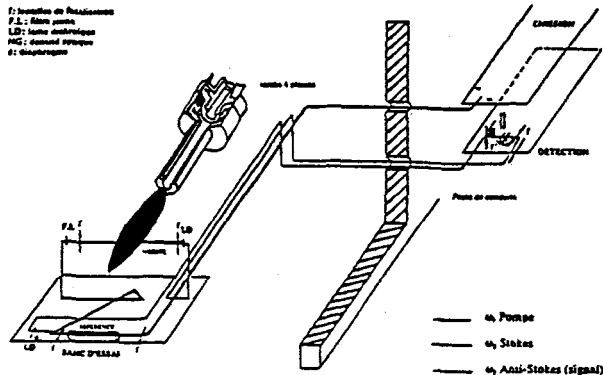


FIGURE 2

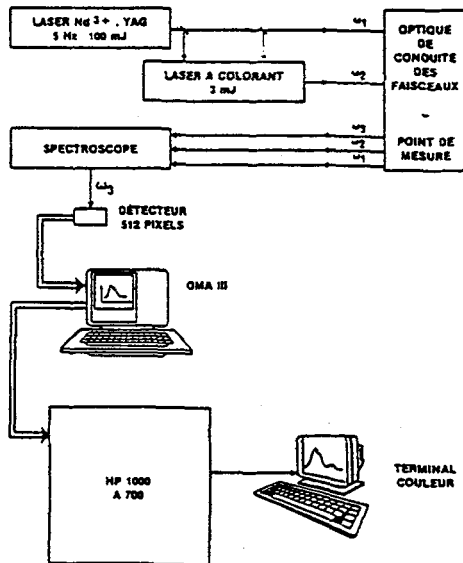


FIGURE 3

RESULTS

The measurements were carried out at cross section D ( $\phi = 17$  cm) [Fig. 1], 77 cm downstream of the coal injector and 244 cm of the plasma torch nozzle. The injected powdered coal consists of 40  $\mu$ m diameter spherical particles, and the coal flow can vary up to 400 Kg/h.

In order to obtain the maximum signal strength and so the SNR, the laser beams were set in parallel polarization configuration. Multiplex spectra were recorded, and it appeared that the non resonant part of the third order dielectric susceptibility became important with respect to the resonant part, leading to an important non resonant background, and so a significant decrease (\*3) of the SNR was observed [Fig. 4].

We moved to a cross-polarization configuration for non resonant background cancellation, introducing a loss in signal strength  $\times 20$ . For a coal flow of 70 Kg/h, the light transmission through the wind tunnel was measured to be 65%. Consistent temperatures, at the center of the stream, were deduced from acquired spectra [Fig. 5].

For higher coal flows (up to 300 Kg/h) the light transmission was found to be only 26%. The SNR became drastically weak ( $\text{SNR} < 1$ ) and the CARS signal was lost among the emission spectrum of the highly luminous media [Fig. 6].

This unwanted noise was acquired for 15 ms (detector photodiodes minimum exposure time), which is much longer than the signal pulse duration of 17 ns. The foreseen solution is to replace this detector by a gated detector with a gate width of 50ns (EGG). This way the noise amplitude will be decreased  $\times 3 \cdot 10^5$ , and so will be enhanced the SNR.

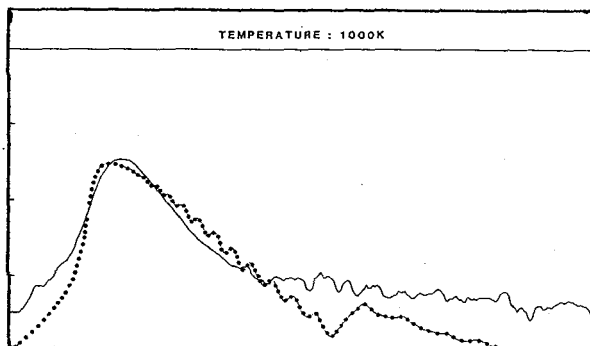


FIGURE 4 : CARS spectra for a coal flow of 70 Kg/h, with parallel polarizations configuration. The important non resonant background precludes any reliable measurement. The solid line is the experimental spectra and the dashed one is the theoretical fit.

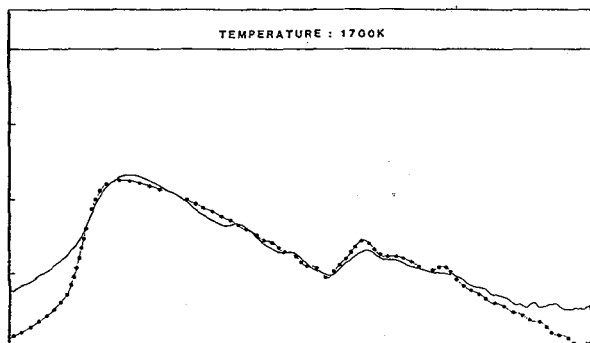


FIGURE 5 : CARS spectra for a coal flow of 70 Kg/h, with crossed polarizations configuration for non resonant background cancellation, involving a loss of signal strength  $\times 20$ . The solid line is the experimental spectra and the dashed one is the theoretical fit.

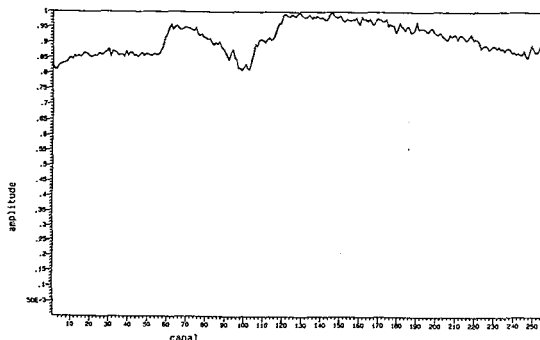


FIGURE 6 : For a coal flow of 300 Kg/h, with crossed polarizations configuration. The CARS signal is lost in the emission spectra of the highly luminous media.

CONCLUSION

We have achieved measurements in different plasma heated gas flow cross sections without coal injection, for numerical models validation. We also have successfully measured temperatures, with non resonant background cancellation, at the center of a burning coal stream for low coal flows (up to 70 Kg/h). The important luminous noise emitted by the media precluded any reliable measurements for higher coal flows (over 100 Kg/h), for our operating conditions. In order to increase the SNR, our CARS bench will be equipped with a gatable detector, with a gate width close to the signal pulse duration (tens of nanoseconds). The experiment will be running on the end of 1987.

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