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MEASUREMENT OF TIME-RESOLVED CROSS-SECTIONAL TEMPERATURE DISTRIBUTIONS IN A THERMAL PLASMA JET

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MOTIVATION

Temperatures in thermal plasma jets are obviously measured using methods characterized by single-directional optical observation and time-averaged data collection. The reliability of results based on a such approach is however doubtful due to turbulent and arc root attachment phenomena leading in most cases to the asymmetry and temporal instability of the jet. Trustful diagnostics of thermal plasma jets in these conditions necessitates thus the development of new tomographic methods with high temporal resolution.

TEMPERATURE EVALUATION

The distributions of plasma radiation in the measurement plane were reconstructed using a method of interpolation of the measured data (transformed to absolute values by calibration with a tungsten ribbon lamp) and the inverse Radon transform procedure in MATLAB environment. Plasma temperatures were found by the comparison of the measured plasma emissivity values with theoretical calculations of argon plasma radiation in the spectral range transmitted by interference filters as a function of temperature in the range 8000–12000 K. The calculations in the considered spectral range 580–730 nm included 115 Ar I lines and continuum radiation.

LINE RADIATION

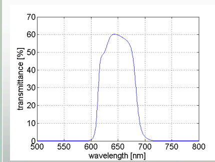
$$\varepsilon_l = \sum_{i=1}^{N} t(i) \frac{h\nu(i)}{4\pi} \frac{g_k(i)}{\sigma} A_k(i) n_0 \exp\left(-\frac{E_k(i)}{kT}\right)$$

N number of lines, *t(i)* transmittance of interference filter at the wavelength of i[th] spectral line, *h* Planck constant, $\nu(i)$ wavenumber, $g_k(i)$ statistical weight of upper level, *s* partition function (we have taken *s*=1), $A_k(i)$ Einstein coefficient for spontaneous deexcitation of the upper level, n_0 concentration of neutral atoms, $E_k(i)$ energy of the upper level, *k* Boltzman constant, *T* temperature. The values of *n(i)*, g_k, $A_k(i)$, $E_k(i)$ for the considered lines were taken from NIST tables.

CONTINUUM RADIATION

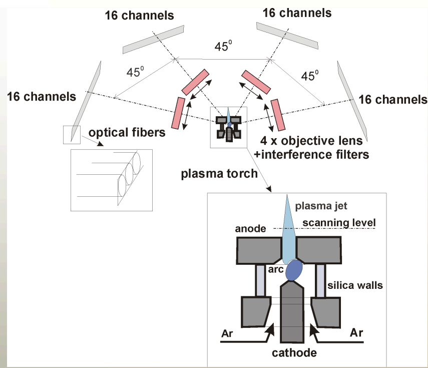
$$\varepsilon_c = \xi \frac{C}{\lambda^2} \frac{n_e^2}{\sqrt{T}} t_f$$

ξ Biberman factor, *C* constant, *l* wavelength, n_e electron concentration, *T* temperature, t_f integrated filter transmittance



Spectral characteristics of interference filter.

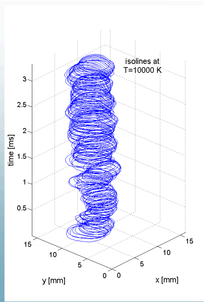
EXPERIMENTAL ARRANGEMENT



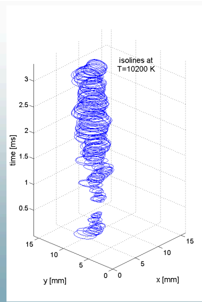
Arc length 5 mm, nozzle diameter 6 mm, arc current 200 A, argon flow rate 1 g/s, plasma jet radiation scanned 5 mm above nozzle, interference filters with the maximal transmittance at 650 nm and spectral width 80 nm, sample rate 468 kHz/channel and record lengths 1 Msample/channel.

RESULTS

The method presents a new effective tool for spatial and time-resolved temperature diagnostics of thermal plasma jets.This way of diagnostics may bring new findings concerning real physical conditions in plasma. In the case of plasma torch fed by d.c.source with some ripple modulation the results show significant differences between temperature distribution shapes and stability in the low- and high-current phases.

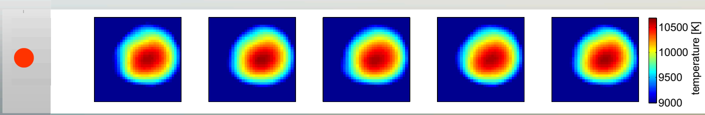


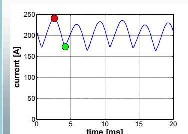
Evolution of isotherms at 10000 K.



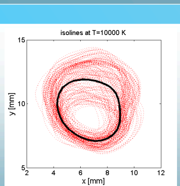
Evolution of isotherms at 10200 K.

Evolution of temperature distributions - high current phase – stable character of distributions (time intervals 2.14 μs, depicted areas approx. 8x8 mm).

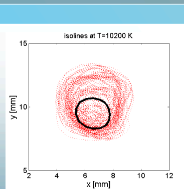




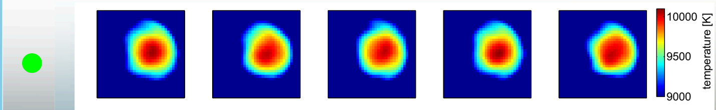
Arc current.



Set of isotherms at 10000 K during 3.33 ms (red) and time–averaged isotherm (black).



Set of isotherms at 10200 K during 3.33 ms (red) and time–averaged isotherm (black).



Evolution of temperature distributions - low current phase – unstable distributions even in the centre (plasma jet core) (time intervals 2.14 μs, depicted areas approx. 8x8 mm).