Closed loop adaptive system with Hartmann wavefront sensor for CO$_2$ laser radiation correction

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Abstract: In this paper we consider the design and realization of wide aperture adaptive system to correct for high power CW CO$_2$ laser radiation. Two new approaches for development of the wavefront sensors to measure 10 µ laser radiation are considered.

It is very well known that the wavefront of the radiation of most of high power lasers is highly aberrated. This does not allow to obtain a good focus and high concentration of the energy of laser beam. As soon as we move to far infrared spectrum (10 µ radiation) there are almost no commercially available wavefront sensors that could be used in this range. On one hand it is understandable – there is a problem with a reliable infra red cameras (arrays of independent sensors) or single sensors. At the same time – most of industrial lasers and laser complexes are still based on high power CO$_2$ lasers with 10.6 µ output!

Here we represent two types of Hartmann wavefront sensors – one – based on bolometer IR camera produced by INO, Canada. Another – is based on Russian technology of thin film deposition on Si substrates. One of the demands of any optical system – is its reliability and ability to work not only in laboratory, but also in the real conditions. From this point of view Hartmann wavefront sensor is the most suitable one to be included in industrial laser. The design of wavefront sensor based on of commercial IR camera has several advantages, such as compactness; convenience to use it for various applications; it is like standard video camera – "plug and play"; possible high resolution. In our case we constructed this sensor based on INO (Canada) IR camera. Below we give the main parameters of a “bolometer” sensor.

Sensor INO160 - Microbolometer uncooled FPA bolometer; 160X120 pixels; 52 mm pitch
Video Output - Gigabit Ethernet Link RJ-45 connector; 16 bit raw data; 8 bit corrected data
Frame Rate - 60 Hz
Number of input diaphragms – 16x16, 20x20
Available Options - External trigger input (opto-isolated); TEC driver; Microshutter electronic driver; Serial interface; Thermistor interface (x2); Random access readout; Real time clock
Overall Dimensions - 65 mm(H) X 60 mm(W) X 105 mm(L)
Weight—230 g

This is a very nice device, but it also has some disadvantages: all bolometer cameras are too sensitive to input radiation (up to 2 W/cm$^2$). And as soon as you want to use them to measure the radiation of some industrial lasers you need to be very careful not to destroy the sensor and to provide a complicated set of filters. Another problem - input window has a limited size. Hartmann sensor based on thin film technology consists of a set of diaphragms and a sensing area - a number of quadrant thermo-electric converters (TEC) made on thin film technology. Main advantage of such wavefront sensor is it could be used with high CW power laser beams and plus large aperture beams might be easily detected. Parameters of proposed sensor are the following:

Wavelength of measurements, 4 – 12 µ;
Input beam size - ring Ø160 x 80 mm;
Number of subapertures – 72;
Range of measurements – 50 µ;Precision of measurements - < 0.6 µ;Frame frequency – 80 Hz;Interfacing port – USB.

As a thermo-electric converters we used the anisotropic quadrant elements made of Si layers evaporated on substrate. It is interesting to point out that main disadvantages of this kind of sensors are continuation of their advantages – they cannot measure small input beams and low CW power beams. At the same time – number of subapertures of such a sensors is also limited by its design. And they have a large size, so it is not very comfortable to install them. As a wavefront corrector we suggest to use a watercooled bimorph deformable mirror. Main advantage of the use of such type of correctors is that they almost perfectly fit the aberrations (mainly thermally induced) of laser beam that need to be compensated. We either use wafer type water cooling system or so called passive cooling system.

CONCLUSION.

We demonstrated two types of wavefront sensors to measure the radiation of CO$_2$ lasers and two types of deformable mirrors to correct for high power CO$_2$ laser radiation. They both have advantages and problems. And only field of application determines which kind of mirror or sensor is the most appropriate.