PARTICLE DETECTION FOR A CO_2 LASER

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ABSTRACT

This article reports on the development of a measurement set-up for high-power CO2 lasers. Measurement task was the identification of particles being dragged with the high-speed flow of the laser gas and carrying the risk of damaging the laser mirrors, and the statistical evaluation of some of their properties.

1 THE PROBLEM

High-power CO2-lasers require quite long light paths to provide sufficiently long interaction lengths with the gain medium. In order to keep the overall size of a laser sufficiently compact the light paths need to be folded in a manner shown in Fig. 1a. The design thus uses a number of mirrors.

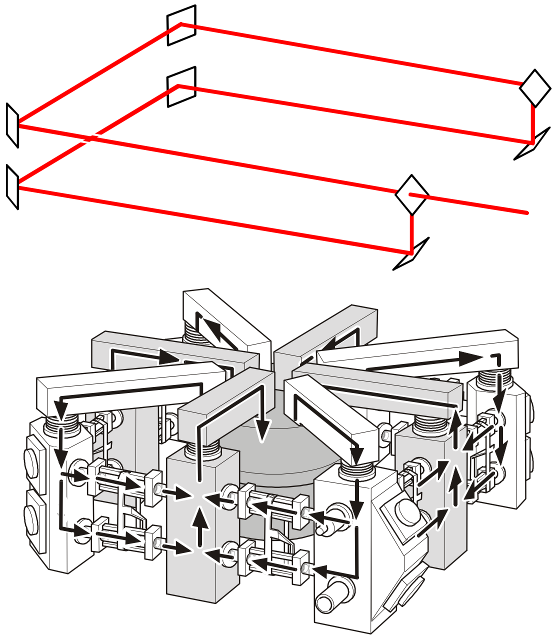


Fig. 1: *Basic architecture of the resonator in a high-power CO2 laser*

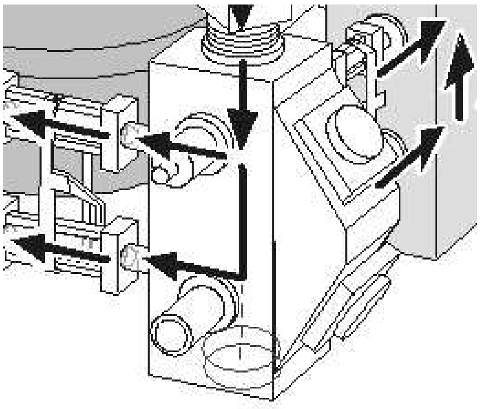
(a) folded light path arrangement

(b) With the flow paths of the gas indicated

The interaction with the gain medium (a gas mixture of CO2, N and He) occurs in the horizontal light path sections. Pumping of the gain medium is provided through RF excitation. The pumping process suffers from high thermal losses and thus leads to a considerable temperature increase. As a consequence, the gas mixture needs to be cooled which is achieved through having the gas circulating in cooling loops as shown in Fig. 1b. The speed of the gas flow in the interaction region is on the order of 180 m/s.

The high speed of the gas requires that the interior of the laser be definitely free of mini particles left there from the manufacturing process or teared off the inner walls during regular operation (e.g., aluminum filings, quartz glass particles, dust, etc). Even though the laser is equipped with grease traps in order to remove particles from the gas circulation, and the gas flow direction is organised such that a free particle is not aiming on a mirror (see Fig.2) some might be left and nevertheless hit the mirror with high kinetic energy. Then they would hit the beam benders like bullets thus damaging the mirror surfaces.

Fig. 2: *Detailed view of beam bender showing gas flow (fat arrows) and grease trap (cylindrical component on bottom)*



2 TECHNICAL CONCEPT

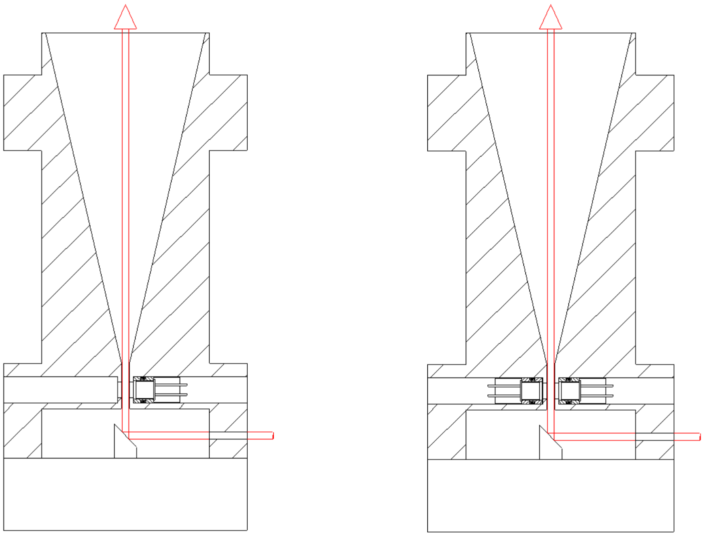
In order to better understand the described process and to further improve the laser design aiming at a higher life time it was proposed to equip the laser with a monitoring system that detects particles in the vicinity of a mirror and determines their velocity. Two concepts appear feasible: A ‘passive’ one detecting the radiation from the particle itself that has been heated by the absorbed laser radiation (see Fig. 3a), and an ‘active’ one consisting of an illuminating (semiconductor) laser and a photodiode (Fig. 3b)

Fig. 3:

Monitoring system, basic concepts:

(a) ‘passive’, using only a photodiode

(b) ‘active’, using semi-conductor laser (LD) + photodiode (PD) (optical axes of LD and PD tilted by 90 degrees)



It can be shown (without going into details of the mathematical treatment here) that the temperature acquired by a particle in the laser beam would provide sufficient radiated power to make possible a detection of the particle. From Wien’s law it can be shown further that under these circumstances (2000 to 4000 K, see Fig. 4) the maximum emission wavelength is on the order of 700-1400nm. This wavelength range can be detected easily using quaternary photodiodes. In our experiments, though, we used a Si diode, type SLD – 67HF1.

Fig. 5 shows the situation with the particle illuminated (and heated) by the IR laser beam and radiating visible light on the photodiode.

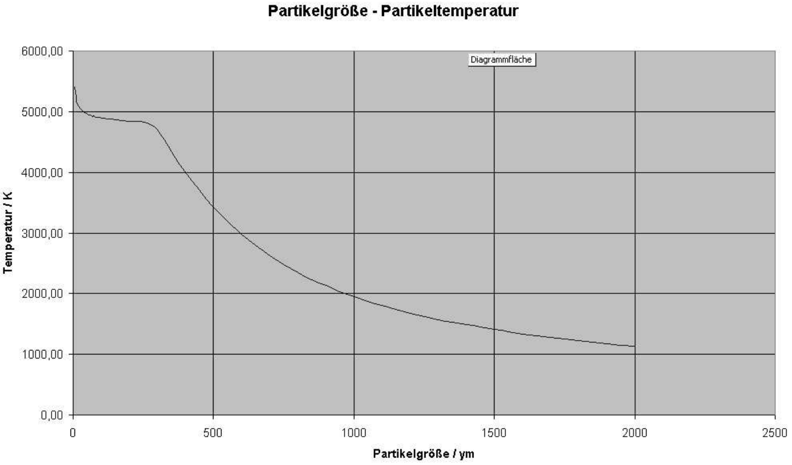


Fig. 4: ***Acquired temperature of a particle after traveling through a distance l=0.2m, with a speed of v=180 m/s, in a laserbeam with P=5 kW***

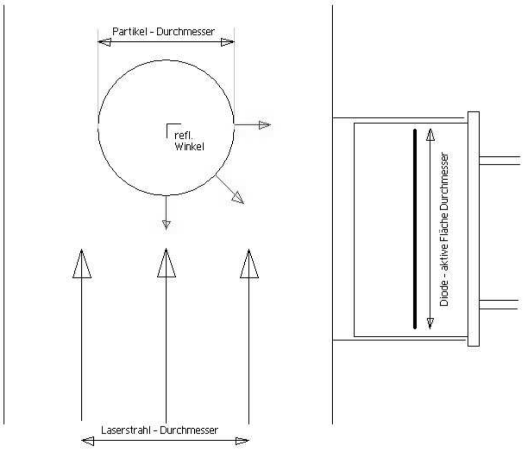


Fig. 5: ***Geometrical situation showing illumination of particle and photodiode***

3 ELECTRICAL SIGNAL DETECTION

The light radiated or reflected off the particle is detected by a photodiode and amplified by a transimpedance amplifier (Fig. 6, inset). Detection of the low light level proved to be very difficult as the measurement environment was heavily disturbed by electromagnetic interference from the high-power high-frequency drive signals of the laser pump system. Therefore, the whole detection circuitry the block diagram of which is shown in Fig. 6 had to be positioned close the detector diode.

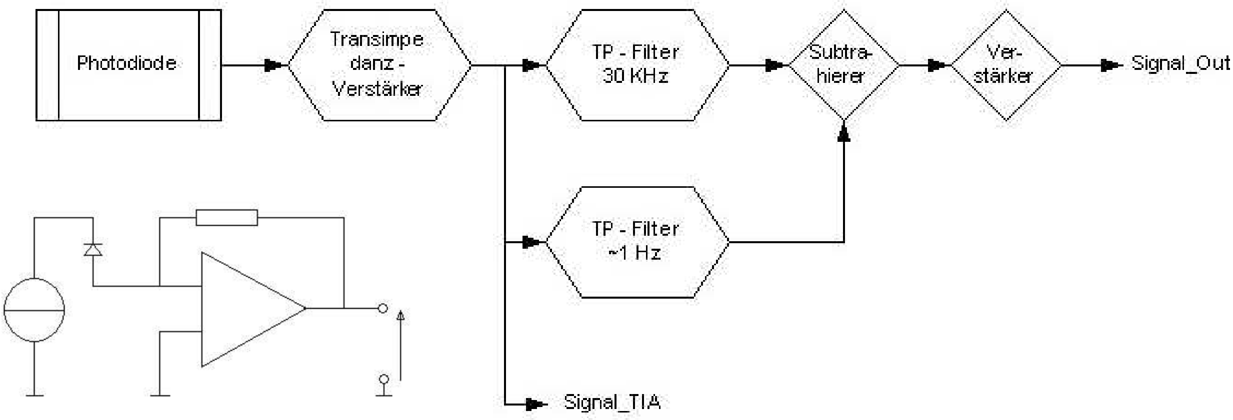


Fig. 6: *Detection circuitry*

One typical signal detected using this set-up is shown in Fig. 7.

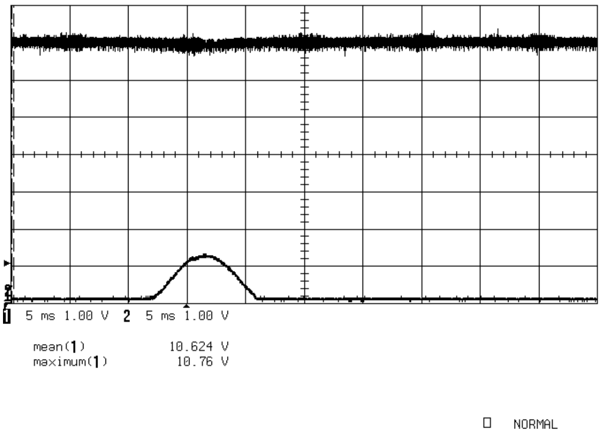


Fig. 7: *Particle signal as measured using the 'active' scheme.*

top: TIA output signal,

bottom: filtered and amplified using the circuit shown in Fig. 6

4 SIGNAL EVALUATION

The output signal from the detection circuitry was evaluated and processed statistically in two different manners, namely, by a PC-based solution using the commercially available software DaisyLab, and by a µcontroller-based concept. Only the latter will be briefly described here. We used a µcontroller from the manufacturer Microchip that had analog inputs on chip. Sampling rate was 30 kHz. The microcontroller evaluates and selectably displays on a 4x40 display the following data:

- number of particles in the last 6 minutes (updated every minute),
- number of particles in the last hour (updated every 10 minutes),
- number of particles in the last 18 hours (updated every 3 hours),
- total number of particles counted,
- amplitude histogram of all particles, scaled in 6 amplitude ranges.

The following table gives an example of the measurement results obtained under specific operating conditions (namely, with particles introduced artificially into the laser):

Time (min)	Particle frequency (*min^{-1})	Signal length (ms)	Number of particles (cumulated)	Remark
0-1	~ 60	~0,4ms	~60	
1-4	~ 30		~150	
4-5	~ 15		~170	
5-8	~ 10		~200	
8-12	~ 6		~230	
12-17	~ 2		~240	
17-20	~1,5		262	Bypass closed
21.		3ms	263	Bypass closed
25.		15ms	264	Bypass closed
31.		8ms	265	Bypass closed

The whole system including the mechanical part (for the conical inlet seen on top of the rear part cf. Fig. 3), the optical illumination arrangement with the laser diode, and the electronics inculding the display is shown in Fig. 8.

Fig. 8: *Photograph of the assembled setup*

5 CONCLUSIONS

In this contribution, a monitoring system for a high power CO2 laser is described that had been set up for investigating the properties and statistics of particles in the laser resonator. Such particles tend to damage the laser mirrors thus reducing the life time of the laser. The system is now under further investigation and will be improved further. The development work described has been performed in cooperation with a known German manufacturer of laser tools.

REFERENCES

[1] Stefan Fliss: Messung der Partikelkontamination in TLF Lasern, unpublished paper, 27.03.2000