COOP-CT-2004-513275

LASERPOM

LOW COST LASER POWERMETER WITH ULTRA-FAST RESPONSE FOR CONSTINUOUS ON-LINE MONITORING OF LASER BEAM POWER AND POLARISATION

Co-operative Research (CRAFT)

Horizontal Research Activities Involving SMEs

# Publishable Final Report

Period covered: from 01/11/2004 to 30/10/2006

Date of preparation: May 2007

Version: FINAL VERSION

Start date of project: November 2004 Duration: 24 Months

Lead contractor: Centre de Recerca i Investigació de Catalunya – CRIC

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# Introduction

The importance of laser technology has steadily increased since its development, and lasers are now widely used in a wide number of different fields, including metrology, welding and cutting in metal industry, surgery and medicine, or telecommunications. For most of those operations, laser power is one of the most relevant operation parameters of a laser system, which determines to a great extent the characteristics of a specific laser operation. The nominal value of the laser power may be affected by several factors, such as thermal stability, long storage periods, supply voltage variations, cleanliness of optical components, or by ageing of the laser tube. Moreover, when optical components such as mirrors or lenses are used in order to either modify the beam path or focus it, variations in the optical alignment can severely affect the power of the beam. For this reason, laser powermeters have become a standard tool for measuring laser power, practically wherever lasers are used

Traditional laser powermeters are based on the measurement of the voltage induced through a calorimetric system when the laser light is absorbed and heats up the detector cell. Such traditional detectors are effective for providing a quite precise figure on the laser power, and they provide a quite flat spectral response. However, they have some limitations that make them unsuitable for some operations.

Increasingly complex laser operations (surgery, laser drilling, holography, etc) demand more and more precise control upon the laser power. Even though traditional powermeters can be used for such purposes, laser power measurements involve interrupting the laser operation, and manually placing the detector in the beam path. Therefore, they are unsuitable for being used as real laser power monitoring systems.

The objective of this project is to develop a laser powermeter based on a novel concept of measurement, which could be used to monitor the laser power during the continuous operation of the laser. Throughout the project, new functional nanomaterials will be developed in order to produce a sensor that will be introduced in a system prototype. The project aims at producing systems able to monitor the laser power of continuous, pulsed and IR lasers.

The consortium of partners participating in the project consists of a number of Small and Medium Enterprises (SMEs), willing to exploit the results of the project, and a number of Research Organisations (RTDs), which are responsible for the main research and developments tasks. Among the RTDs, the UB-FEMAN group of the University of Barcelona contributes to the project with their expertise in nanotecnology. Bay-Zoltan Insitute will take a major role in the test and validation of the system to be developed during the project. Finally, FKK and CRIC are responsible for the development of the mechanical design, electronics and software for the instrument. In addition, CRIC also coordinates the project. The group of SMEs in the consortium contains a well-balanced number of technological companies which can lead the commercialisation of the instrument (Lasercomponents GmbH, JCB electromecanica SL and Laserpoint Srl), as well as “end-user” companies, interested in the instrument itself due to its potential applications in their particular business (TEMSA Diamond division SA, Carcelle Ultrasonidos, VARADI & Társai Ltd, CeramOptec GmbH and Spectrum Technologies PLC).

After the first year of the project, the nanomaterials required for producing the instrument have been successfully developed and characterised. Laboratory measurements have demonstrated the feasibility of measuring laser power based on the proposed method. A first prototype has been already produced, exhibiting good enough sensitivity and excellent linearity.

During the second year of the project, the performance of the prototype will be systematically characterised and optimised. The system will be tested and validated using different laboratory and industrial lasers. On the other hand, it is foreseen that the SMEs will proceed with the exploitation of the project results by patenting the developed technology, carrying out a detailed market analysis, and producing an adequate exploitation plan.

# Description of the consortium

The consortium is composed of a number four RTDs, which are responsible for carrying out the technical and scientific tasks related to the workplan. In addition, eight SMEs participate in the project, which will help mainly in the test and validation of the system, and will also ensure the exploitation of the technology developed. The following table describes the partners involved:

| **Partic. Role*** | **Partic. Type**** | **Partic.no.** | **Participant name** | **Participant short name** | **Country** |
|---|---|---|---|---|---|
| CR | SMEP | 1 | JCB Electromecánica SL | JCB | Spain |
| CR | SMEP | 2 | Laser Components GmbH | L-COMP | Germany |
| CR | SMEP | 3 | LaserPoint Srl. | L-POINT | Italy |
| CR | SMEP | 4 | TEMSA-Diamond Die Division S.A. | TEMSA | Spain |
| CR | SMEP | 5 | CARCELLE ULTRASONIDOS | CARCE | Spain |
| CR | SMEP | 6 | VARADI & Társai Ltd | VARADI | Hungry |
| CR | SMEP | 7 | CeramOptec GmbH | CEROP | Germany |
| CR | SMEP | 8 | Spectrum Technologies PLC | SPECTECH | UK |
| CO | RTD | 9 | Centre de Recerca i Investigació de Catalunya, S.A. | CRIC | Spain |
| CR | RTD | 10 | Physics and Engineering of Amorphous Materials and Nanostructures group, University of Barcelona | UB-FEMAN | Spain |
| CR | RTD | 11 | Feltalálói es Kutató Központ Szolgáltató - Innovation and Research Center Services Company Limited | FKK | Hungry |
| CR | RTD | 12 | Bay Zoltán Institute for Materials Science and Technology | BAYATI | Hungry |

*CO = Coordinator
CR = Contractor

**SMEP
RTD
OTH

JCB S.L (1), is a Spanish SME whose main activity is based on electronic applications within industrial environments. They have vast experience in artificial vision and sensory equipment and are particularly known for developing low cost solutions for industrial applications. They are involved in the laser industry, and more specifically, in the marking industry. Being aware of the market need to supply a low cost solution for laser power measurements, they intend to exploit this totally new nanotechnology application. LASER COMPONENTS (2) is a German company producing a wide range of products within the laser world, among them powermeters, pyroelectric sensors, optical products, etc. They have also “in-house” facilities and expertise in surface deposition technologies, which are useful for the project. They have provided very good feedback about the world of powermeters. LASERPOINT (3) is another manufacturer of laser power/energy meters, based in Italy. They have provided accurate information on details related to the sectors in which *LaserPom* is going to be applied, hence complementing the market information provided by Laser Components. Their experience in laser powermeters has been essential in the development and integration system stages of the project. TEMSA – Diamond Die Division (4) is a Spanish company whose main activity is focused on the production of diamond and PCD rows used in drawing hard wires (copper, steel, tungsten and others). Several steps of the fabrication process involve the use of laser processing for drilling. Their skills and know-how in laser drilling has been especially useful in the test and validation process, while they have also participated actively in the prototype development contributing with their experience as end-user of lasers. CARCELLE ULTRASONIDOS (5) is a Spanish SME whose main activity is that of industrial finishing processes, mainly in marking and engraving using laser techniques. It is an end-user in a different sector within the material processing industry. VARADI (6) is a Hungarian firm working in the cutting sector, which is one of the most important sectors of laser material processing. VARADI will give an important input from this sector. CERAMOPTEC (7) is a well known German company, working in different fields related with optical fibre and medical products. They are leaders in advanced medical lasers, fibre optic laser delivery systems, and medical endoprobes. Due to their experience in medical equipment, and the relevance of the medical sector for the proposed project, CERAMOPTEC will play a key role in the test and validation phase of the project. Furthermore, the proposed technology can be **easily transferred to a wide range of sectors**, where the need for monitoring laser beam is strong. These include laser applications for chemical/biological analytical instruments, active-safety systems, telecommunications, etc. Finally, SPECTECH (8) is a company pioneer to develop industrial systems for laser marking and stripping of wires for microelectronics. The aeronautic industry is their most important customer. They are preferred suppliers of important companies such as Boeing Company. SPECTECH are interested in the project since they hope to be able to implement this instrument for monitoring the striping and marking processes of conductor wires. These applications require very tight control of the laser energy, since the objective of using laser processing is mainly to avoid damaging the conductor wire. SPECTECH expects to improve their process control and yield through incorporating *LaserPom* into their systems.

# Summary of project results

During the project, three prototypes were developed. All of them were based on the use of optical active surfaces containing nanoparticles. Silicon nanoparticles were obtained using Plasma Enhanced Chemical Vapour Deposition (PECVD), and also by using a chemical process (sol-gel). These elements were useful for sensors operating in the UV-Vis-NIR range. For the Mid-IR range corresponding to $CO_2$ lasers, ZnSe nanoparticles were used. The optical elements developed provided excellent results, even though they use was limited to moderate laser powers, particularly in the mid-IR range.

Prototype A was designed to monitor the laser power of lasers operating within the UV-Vis-NIR range. The system developed showed an excellent linearity over the full dynamic range, having a limit of detection of 0.1 mW and a dynamic range of four decades. The accuracy and precision of the system was good (better than 1%), even though its performance depends on the quality of the optical alignment (beam misalignments may induce an error of up to 10%) in the sensor readout. Furthermore, the bandwidth of the sensor is up to 100kHz. Finally, the sensor provided also information on the polarisation angle of the incoming beam, with an accuracy in the determination of the azimuthal polarisation angle of 5º.

Furthermore, a second prototype was produced based on the same concept, but specifically intended for fiber coupled lasers. In this case, it was assumed that the output of the fiber was randomly polarised light. The system can provide accurate measurements of the laser power in the range 0.25W-250W. Furthermore, the use of a mechanical holder to fix the fiber during the measurement minimises the risk of accident and/or of damaging the sensor.

Finally, a third prototype was produced to monitor the power of industrial $CO_2$ cutting/welding laser systems. Also in this case, a high degree of linearity was achieved within the power range 0-30kW, with an accuracy error of 50W. Response time of the system was only 100 msec.