IMPROVEMENT OF ADJUSTMENT COMPONENTS FOR PRECISE MEASUREMENTS OF OPTICAL SIGNALS

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Abstract: The importance of well adjustable optical system is considered essential whenever reliable results are expected to be delivered. In this paper we focus on optical components for precise measurement of generated light signals in fundamental research. The proposed upgraded components are to be used in laser based experiments. With improved precision of pointation and system stability we aim to gain reproducible and robust data even in sensitive experiments which deal with detecting weak optical signals. Described technical solution even spares time needed to adjust the whole optical system. All described components have to deal with special environmental constraints like high noise and vibration level.

Keywords: Adjustment, optical settings, precise measurement, laser, physical experiment

1. Introduction

Laser experiments provide vast opportunities in fundamental research. Components described in this paper were designed as a part of improvement of a laser system used for experimenting with photons and magnetic field. Proposed experiments cover research of new subatomic particles, experiments with polarized light passing through strong magnetic field and other. Since the optics already implemented in the experiment worked well but was too much sensitive on vibrations and very difficult to adjust, some upgrade was necessary. Improvement of optical systems is based in upgrading the fixing mechanism and adjustment options.

2. Outline of the Experiment

While designing, we have proceeded from current specific setup of a laser experiment. The experimental setup contains magnetic dipole magnets, cryogenic cooling system, vacuum pumping system, laser unit, and several control and data acquisition units. In this paper we will just focus on the optical adjustment system of the laser (on figure 1). The laser beam is generated in a 4W@528 nm Ar Ion laser (position 1 on figure 1). Then it is directed to the experimental device using two reflecting mirrors which enables alignment and proper positioning of the laser beam. Since the mirrors do not reflect all the incoming light, we can use the light transmitted through the glass interface for diagnostics purposes (position 5 and 6 on figure 1). Laser beam diverges by its nature. That’s why a beam expander (position 4 on figure 1) is used to decrease the angle of divergence. The beam then enters the experimental chamber. A spatial filter can be also used to filter noise and aberrations in the laser beam. Finally the beam is focused to a detector.

Figure 1: Simplified scheme of the optical adjustment system
1 – source of the laser light
2 – 1st reflecting mirror
3 – 2nd reflecting mirror
4 – beam expander
5 - diagnostics
6 – diagnostics

Current setup of the experiment needed some improvements to get the experiment to higher performance levels. The one improvement should be in quality, the other one in quantity. Quality improvement is done using better components that ensure reproducible and reliable setting of the system. The idea of the quantity improvement is...
based in increasing the laser power using an optical resonance cavity that multiplies gained power.

3. Environmental conditions

Generally speaking, all external conditions may influence the experimental setting. We are able to monitor basic parameters of the working environment – air temperature, humidity and pressure. These help up to recognize any fundamental changes in the measurement conditions, whereupon we check the accuracy of the optical adjustment. Based on a long-term measurement of the working conditions, we may assume the external environment as more or less stable during the year. There are negligible changes in air temperature during the day. So we have to calculate with thermal expansion of the materials only in small interval of values.

The whole experiment is situated in a busy hall. There are some sources of vibrations from the cryogenic and vacuum systems, from air-conditioning, traffic, and working. We have identified these sources and tried to eliminate their influence with the design.

4. Design of the reflecting mirrors

The two reflecting circular mirrors (position 2 and 3 on figure 1) guide the laser light from the laser output coupler to the experimental and measurement devices. Damage threshold of used mirrors is 1 kW/cm². The limit beam diameter is 0.5093 mm@4W which is highly sufficient since the measured output beam diameter is 0.7085 mm.

The mirrors are mounted in a gimbal (see figure 2). It enables moves in azimuth and elevation directions. Stability of this mount is reliable with high resolution. Friction in the guidance is minimized using preloaded angular contact bearings. This mount provides repeatability, negligible backlash and small hysteresis. Positioning can be done in large, more than sufficient range. For rotary (or azimuth) movement it is 360°. For elevation it is about 270°.

The static adjustment is usually done manually only once when the working conditions significantly changes or when the system needs readjustment before a new measurement starts.

The use of actuators can be also discussed, if their unit cost will not prevail their benefits in this case. The actuators should be equipped with incremental sensors (IRC) for measurement and feedback controlling of the actuators.

The back of the mirror holder contains transitional mounting ring with a thread for mounting of the diagnostic wavefront sensor or other diagnostic device.

All metallic parts made from duralumin are eloxed to prevent reflection of the stray light.

The diagnostic system takes advantage of approximately 2% of transmitted light energy through the reflecting mirrors with 98% reflectivity coefficient. The wavefront sensor is placed in the straight direction after the first mirror interface in the light path (see position 5 on figure 1). The wavefront sensor provides information about the quality of the beam profile and transverse intensity profile. The second interface (see position 6 on figure 1) can be used for beam energy measurement.

5. Design of the beam expander

The beam expander decreases divergence of the laser beam. The lens collimates the output beam to a larger diameter, which is a notable side effect. The Keplerian telescope consists of positive focal length lens (see figure 3).
Improvement of Adjustment Components for Precise Measurements of Optical Signals

Position of the objective and eye lens of the expander has to be very accurate to get the finest Gaussian laser spot at the detector position. Also we have to avoid backlash, hysteresis and inaccuracies in the guidance.

The beam expander (position 4 on figure 1) is placed on a conventional movable XYZ stage for coarse position adjustment. The stage can be easily fixed to the optical bench using common fixing T-bolts.

The optical components have to be adjusted in three dimensions and angular displacement. The lens (position 4 on figure 4 and 5) are mounted in a stiff holder (position 8 on figure 5) and fixed with three clamps. The holder is connected with the frame structure (position 1 on figure 4 and 5) through flexible membrane (position 6 on figure 4 and 5). The membrane is fixed with 18xM3 screws (position 8 on figure 5) around the whole inner perimeter.

The finest adjustment of the lens is based on flexural elements to get excellent accuracy free from backlash. Small range of moves is given by maximal allowed straining but is sufficient for the finest setting of the optical component. The flexural elements are three 1D hinges in form of wires. They are stifferly connected to the expander frame. The wires enable small angular and XY displacement of the lens holding frame. They can also be replaced by a double-ball joint, but a wire has much convenient design, with no coulomb friction based slip-stick effect and low manufacturing costs.

The three-point method of mounting is a very efficient way that provides enough constraints for all degrees of freedom. The displacement is induced using micrometer screws (position 5 on figure 4 and 5) or Piezo actuators. The adjustment screws are placed at 120° intervals. They provide also fixing of the set position of the lens.

Both lenses are mounted separately using the described mechanism. Focusing of the laser beam is done by changing the zoom of the objective of the expander. There are several ways how the two lens unit can be connected. They can be connected using simplified slide bearing when the inner surface of one unit is finished and the second one has a coarse thread cut on its outer surface. The thread is filled with epoxy resin which has approximately 1% solidification shrinkage which provides enough backlash in the support for smooth but exact movement.

The other way, similar to the first one uses a thread cut in the outer surface again. But this time a corresponding thread is cut also on the inner surface of the other unit. A wire is wounded in the thread and fixed and works as a slide way (see figure 6). The other method uses a bellow to connect very flexibly the two units. Fixing of the position of the bellow is done again using a three-point mounting method (see figure 7). The bellow enables tilting of the lens and enables to compensate deviations from the optimal position.

Such easily adjustable components enable to fix and mark the position for further use. Time needed for adjusting the laser system is reduced from days to several hours. The stability of the measurement is limited by time intervals between two major vibration shakes caused by moving of heavy
equipment in the laboratory hall. These vibration shocks do not necessarily change the setting of the system, but the urge to check the alignment is highly recommended.

6. Conclusion and Outlook

Described components are designed and analyzed for experimental purposes. The aim of these components is to increase stability of the setting of an optical system. The other benefit of this upgrade is in decreasing of the time needed to adjust the laser optics. Because the expander and the mirrors are applied with Class IV laser, the used optical components have to have high damage threshold to withstand the peak energy of the laser. In few months they will be prototyped and then tested in situ. If any external constraints additional appears, the design can be flexibly adapted to different conditions.

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