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On the use of small integrating spheres to improve the linearity range of RASNIKS systems

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Departamento de Fusión y Partículas Elementales

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"On the use of small integrating spheres to improve the linearity range of RASNIKS systems"

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16 pp. 5 figs. 5 refs.

Abstract:

Rasniks elements will be used in the CMS alignment system. The large displacements of the different subdetectors expected in the CMS experiment demands large linearity response of this system. By the use of a small integrating sphere we have optimized the source definition such that a factor three improvement in the linearity range with respect to conventional Rasnik configurations is obtained. The response range reached coincides with the maximum one can get with the components used in the test.

"Sobre el uso de esferas integradoras en la mejora del rango de linearidad en sistemas RASNIK"

Alberdi, J.;Burgos, C.;Ferrando, A.; Molinero, A.; Schvachkin, V.; Figueroa, C. F.; Matorras,F.; Rodrigo, T.; Ruíz, A.; Vila, I.

16 pp. 5 figs. 5 refs.

Resumen:

Sistemas de tipo Rasnik serán utilizados en el alineamiento de CMS. En este experimento se esperan grandes desplazamientos de los diferentes sistemas de detección, por lo que será necesario amplios rangos de linearidad en los Rasniks. Mediante el uso de pequeñas esferas integradoras hemos conseguido aumentar en un factor tres el rango de linearidad de sistemas Rasniks convencionales. El rango de respuesta conseguido coincide con el máximo que puede obtenerse con los componentes utilizados en el test.

1 Introduction

Multi Rasnik [1] systems are foreseen as possible straightness systems on the alignment of the muon detector [2] in the CMS [3] experiment.

Rasniks were first developed by NIKEF-H Physics Institute, and they have been extensively used for the automatic monitoring of the alignment of high energy physics detectors.

From first estimations, the alignment instruments of the CMS Muon System will need to monitor displacements in the range from mm to 2-3 cm [3]. The expected movements or displacements are due to the magnetic field forces (originated by a 4 T solenoid [4]), thermal effects, gravity, etc. Hence, one of the first goals is to increase the linearity response range of the conventional straightness systems [5] to cope with the monitoring of large displacements.

Starting with the original concept of the Rasnik system, consisting of a light source, a lens and a fotodetector we have made modifications on the light source definition to improve the light homogeneity by the use of a small size integrating sphere leading to a maximal increasing of the linearity range of the used Rasnik.

2 Experimental setup

The experimental layout is shown in fig. 1. A simple set of a Rasnik system was installed on an optical bench of solid granite block. The temperature of the room was kept constant at 22 ± 1 ^{o}C. The beam emitted from the light source travels 2 m till the lens which focuses the diffused light on the photodiode placed 2 m far from the lens. The light spot iluminating the photodiode produces a photocurrent which is analyzed by an adequate readout electronics.

The light source, lens and photodetector are mounted on a Rasnik block as shown in fig. 2.

We have taken data with two light sources. The first is a conventional one, referred to as "LED", and is composed of a LED, a diffuser and a square mask. The LED emits with a peak luminous intensity of 3 cd at λ = 660 nm. The square mask gives a well defined square beam profile.

The second light source, referred to as "integrating sphere", consists of a diode-laser illuminating an integrating sphere which diffuses light through a square mask. The diode laser emits at λ = 670 nm and the typical output power is 4 mW.

The integrating sphere (see fig. 3) is used to improve the homogeneity of the output light beam. We expect by that to enlarge the linearity range of the Rasnik response. The dimensions are compatible with the optical passages foreseen in the CMS alignment system. Reflection of light in the inner wall of the sphere is done by a radiation hard white paint.

The lens used has a focal length of 1 m and produces a one-to-one image of the light source onto the photodetector. As photodetector we have used a quadrant photodiode with a responsivity of 0.46 A/W at λ = 670 nm. This device is a segmented position sensing detector and has four distinct photosensitive segments (A,B,C,D) separated by a 200 μm gap (see fig. 4).

Each quadrant photodiode was connected to a readout box where the photocurrent is converted to voltage and then amplified. The resulting analog signal from this step is digitized with a 12 bits resolution. The DAQ is carried out by a PC, and it is possible to do an online monitoring of the system.

The position of the square light spot with respect to the center of the quadrant photodiode is given by:

$$X = [(A+D) - (B+C)] \times (L-h)/2(A+B+C+D)$$
$$Y = [(A+B) - (C+D)] \times (L-h)/2(A+B+C+D)$$

where A, B, C and D are the photocurrents produced in each quadrant (fig. 4), L is the length of one side of the light spot and h is the width of the gap between quadrants. Note that theses equations are independent of the variations of the light intensity.

3 Results

The linearity of the reconstructed position was studied by moving the photodiode in steps of 100 μm along the horizontal direction (transverse to the bench). The linear range is determined by a linear fit to the data. The results are shown in fig. 5 where we plot the readout (in ordinates) versus the mechanical displacement of the photodiode. The data are normalized to have a value of one for the tangent in the linear range.

We found that the range of linearity with conventional LED (full line in fig. 5) if of ± 0.50 mm, while we measure ± 1.50 mm when the integrating sphere is used (dashed line in fig. 5).

Note that the range of linearity obtained with the integrating sphere represents the maximum value one can get with the dimensions of the used quadrant-diode (50 mm^2 active area) and the size of the spot light (4x4 mm^2).

4 Conclusions

We have presented a first experimental result of the Rasnik performance when a new light source using a diode-laser and a integrated sphere are used. With this configiration we have obtained a linearity response range of ± 1.5 mm, three times higher than using conventional source arrangements (± 0.5 mm). The response range is now limited by the geometry of the photosensors used in the test. We then conclude that ranges in the two to three cm are achievable by using larger photosensors and light sources.

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[2] C. Burgos, "An alignment system for the CMS experiment", CMS TN/94-198.
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[5] P. Duinker et al., Nucl. Instr. and Methods A 263 (1988) 14.

Figure captions

Fig. 1: The experimental setup.

Fig. 2: Front view of a Rasnik block.

Fig. 3: Sketch of the integrating sphere.

Fig. 4: Detail of the quadrant photodiode.

Fig. 5: Linearity of the reconstructed position using the integrating sphere (dashed line) and a conventional LED (full line).

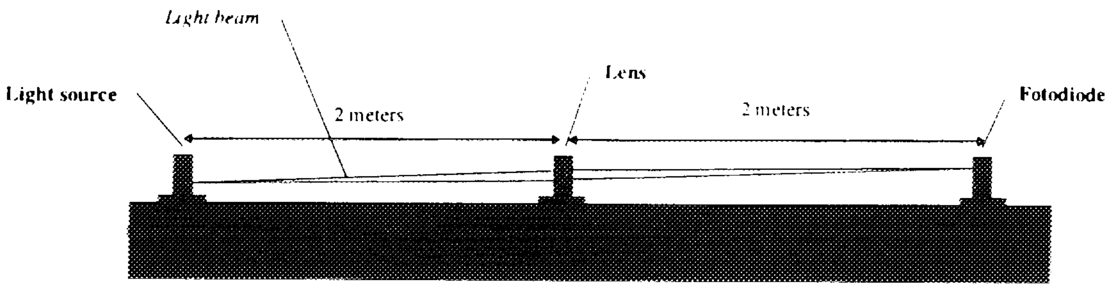


Figure 1

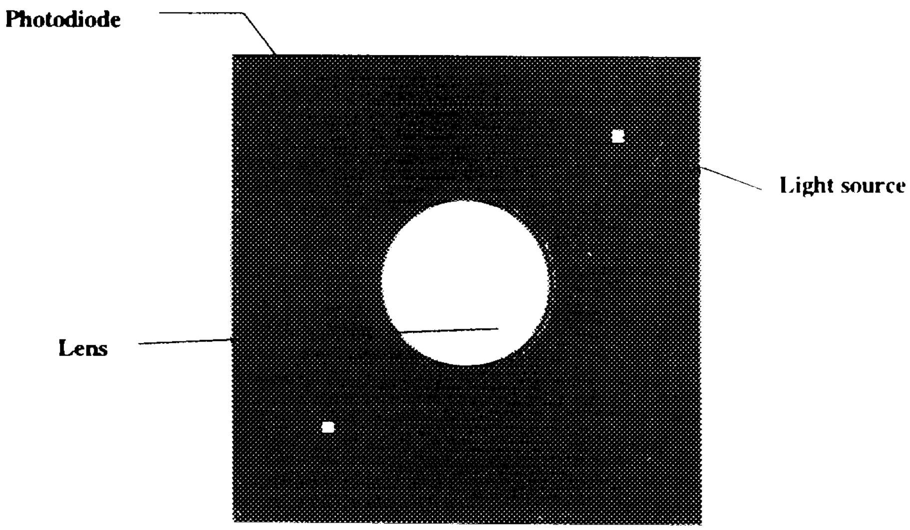


Figure 2

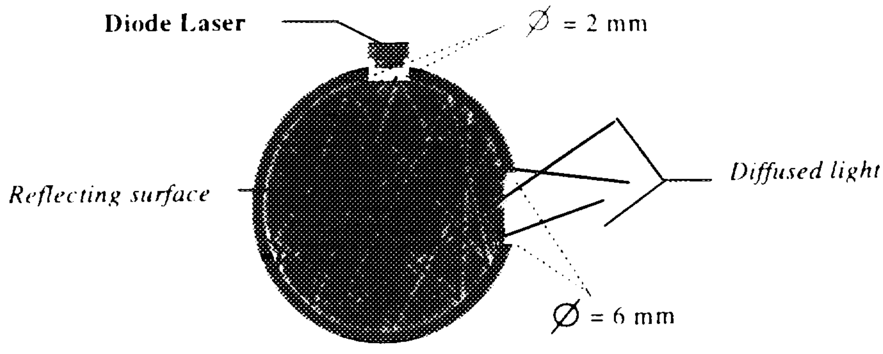


Figure 3

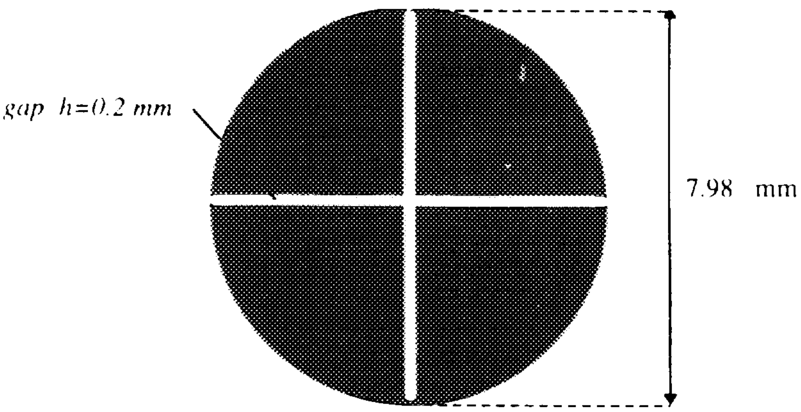
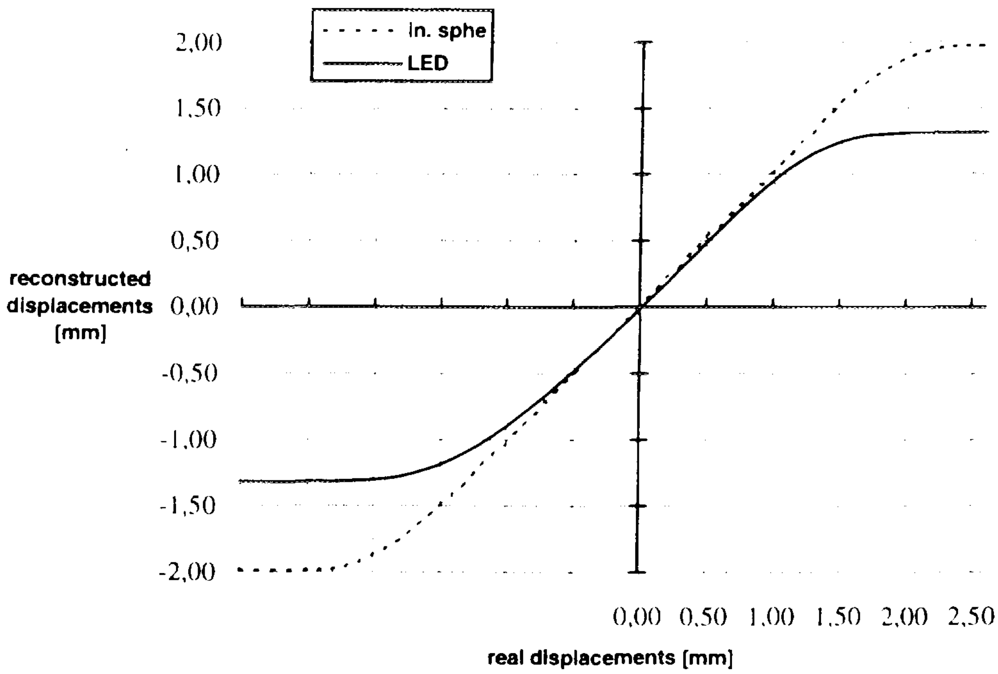


Figure 4



ln. sphe
LED
2,00
1,50
1,00
0,50
reconstructed displacements [mm]
0,00
-0,50
-1,00
-1,50
-2,00
0,00 0,50 1,00 1,50 2,00 2,50
real displacements [mm]

Figure 5