Online Inspection Uses Telecentric Laser-Scan Lenses

by Konrad Hentschel, Sill Optics GmbH & Co. KG, Wendelstein, Germany

The setup for online inspection through a scanning lens includes components that upgrade typical laser marking systems for this application.

Online-Inspektion verwendet telezentrische Laser-Scan Linsen

Der Aufbau für die Online-Inspektion durch Abtast-Linsen enthält Komponenten, die typische Lasermarkiersysteme für diese Anwendung erweitern.

L'inspection en ligne utilise pour le balayage laser des lentilles télécentriques

La mise en place d'une inspection en ligne par scanner intègre des composants qui facilitent et rendent plus performants des systèmes typiques de marquage par laser.

Tecniche di controllo ottico in tempo reale sfruttano le lenti telecentriche dei sistemi per laser scanning

L'apparato per il controllo ottico istantaneo attraverso la lente usata per la scansione del fascio laser include componenti che migliorano le prestazioni dei normali sistemi laser impiegati in queste applicazioni.

Online inspection as part of an integrated and failure-free production process is becoming the most critical element in modern manufacturing plants. To weld, mark or cut material with high-power lasers and online control is difficult for many reasons.

It is easy to upgrade a typical industrial laser marking system for online inspection by adding a beamsplitter to take part or all of the reflected light to a camera. The other required components are a camera lens and an illumination source.

Separating the working and inspection wavelengths requires a dichroic beamsplitter with 100 per cent transmission at the laser wavelength and 100 per cent reflection at the inspection wavelength. In scanning systems, the scanning mirrors must be highly reflective for the two wavelengths, and the focusing or scanning lens should maximize the transmission for both.

Camera and lens

When the camera chip is sensitive to the laser wavelength, as it is in most cases, reflections in the beamsplitter should be prevented from entering the camera by adding a blocking filter. The camera lens can be standard, and its focal length defines the field of view of the system. For example, when the focusing lens has a focal length of 100 mm and the camera lens has a focal length of 50 mm, the magnification on the CCD is 50/100 = 0.5×. So the field of view for a ½-in. CCD is 12.8 × 9.6 mm.

It is not practical to use the laser light itself for inspection, because the beamsplitter will divert part of the light that is intended for the workpiece. Also, the beam intensity is much too strong for the camera. Therefore, the inspection wavelength must be different from the laser wavelength.

Ringlights and dark-field illuminators are commonly used, but they are not always the most effective solution. It is better to illuminate through the beamsplitter and lens. An appropriate light source is a collimated LED with a centre wavelength that differs from that of the lasers.

The collimated LED beam is combined with the laser beam and focused directly on the area of interest. This optimizes the intensity and equalizes the light distribution over the complete scan area.

This system seems straightforward and, therefore, easy to install. But there are serious problems that must be addressed. The intensity ratio of laser light to inspection light on the camera must be adjusted to account for the energy density in the beam spot and the reflectivity of the workpiece. Blocking filters must be applied to the laser light to avoid a hot spot in the centre of the image.

The loss of light as the beam passes through many optical components is quite high, so these components need antireflection coatings optimized for both wavelengths. Also, the numerical aperture of scanning systems is small. A system comprising a scan lens with $f = 160$ mm and a scanning mirror system for a 10-mm-diameter beam has a numerical aperture of only 0.032.

Difference of field of view

Scanning and welding systems usually work with monochromatic lenses, which are strongly dispersive and which cause the focal length to change with wavelength. The camera lens can be easily adjusted to bring the workpiece back into focus.

In single-spot systems such as nozzles, this works perfectly. But in scanning systems, the area of interest is different. The image height y' is directly proportional to the focal length, so that $y' = f \cdot \text{Theta}$, where f is focal length and Theta is the scan angle in radians. A change in focal length causes a change in the image height as well. For most scan lenses, this is a critical factor. For example, $f = 160$ at 1064 nm means that $f = 150$ at 660 nm. For inspection at 660 nm, the image height is different at the edge of a 25-mm-diameter field by roughly 5 mm. With 1:1 imaging to the 4.8 × 6.4-mm CCD sensor, one is already outside the visible field of view.

This problem cannot be corrected with any standard scanning lens. The only solution is a colour-corrected scan lens, which has nearly the same focal length at the laser and inspection wavelengths.

Scan lenses show strong field distortion because of their *f*-Theta correction and their perspective error caused by the large viewing angle through the lens. Both dramatically

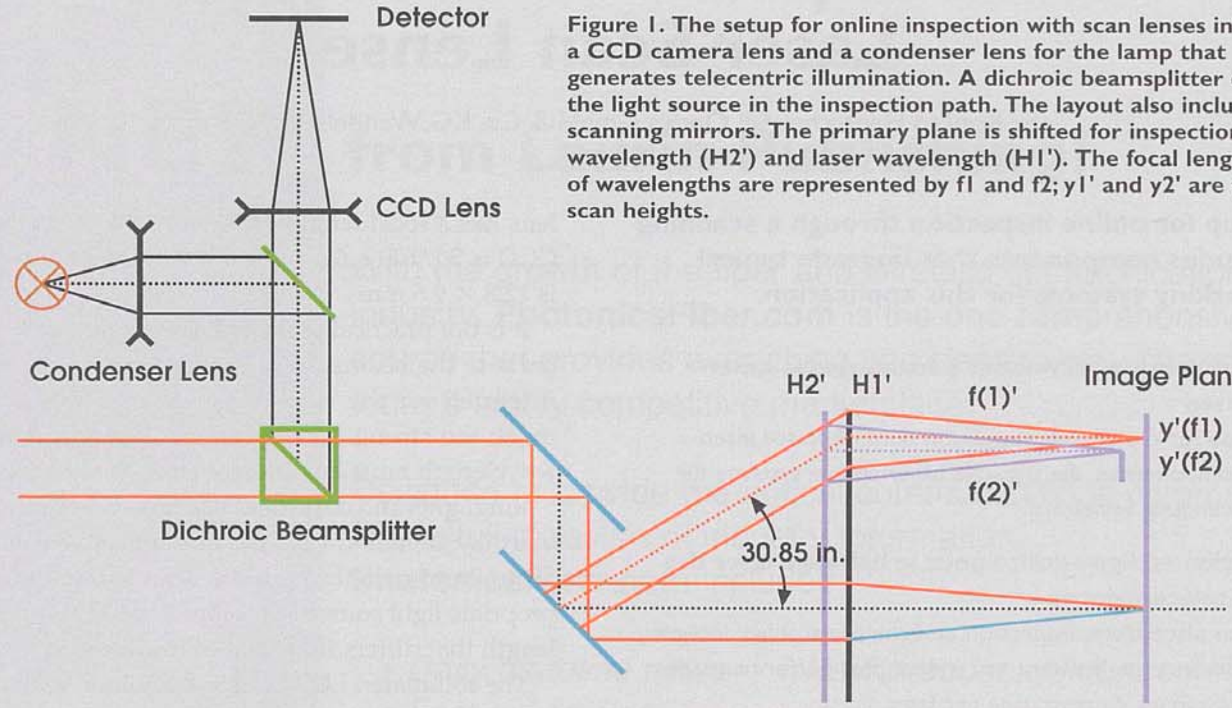

Figure 1. The setup for online inspection with scan lenses includes a CCD camera lens and a condenser lens for the lamp that generates telecentric illumination. A dichroic beamsplitter couples the light source in the inspection path. The layout also includes 45° scanning mirrors. The primary plane is shifted for inspection wavelength (H2') and laser wavelength (H1'). The focal lengths of wavelengths are represented by f1 and f2; y1' and y2' are the scan heights.

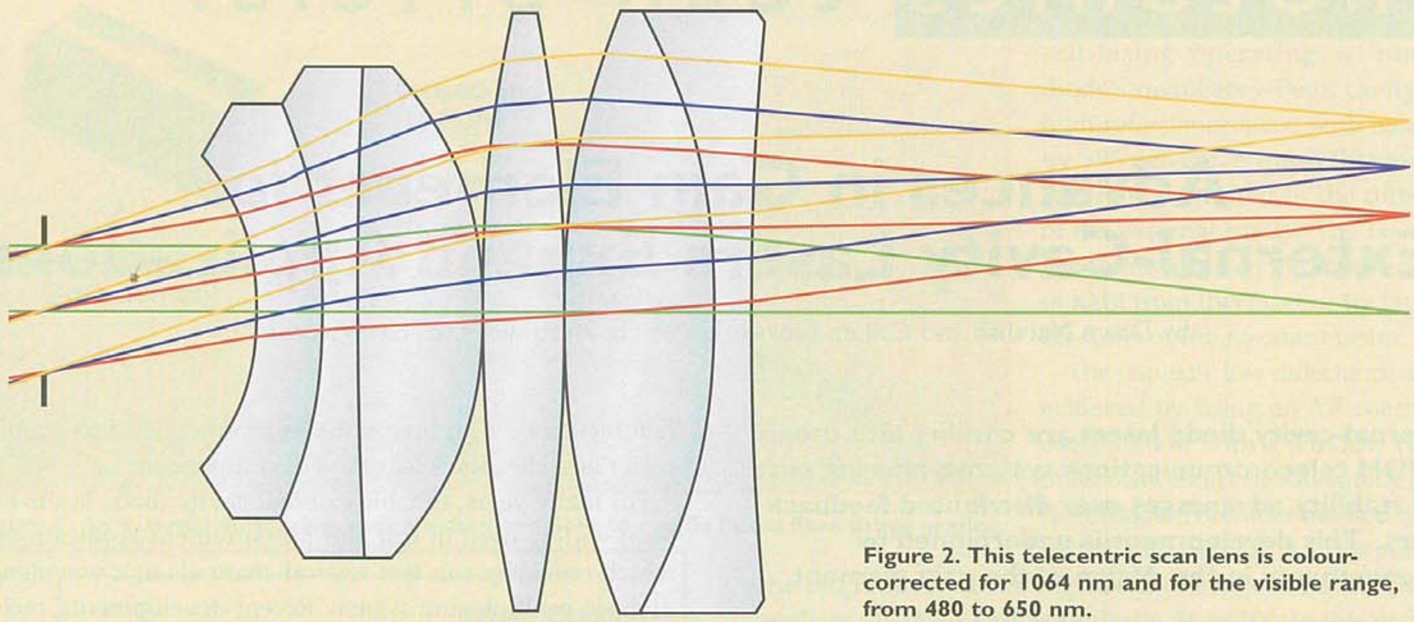

Figure 2. This telecentric scan lens is colour-corrected for 1064 nm and for the visible range, from 480 to 650 nm.

deform the image at the edge of the field, rendering calibration for automatic control very difficult. This can be solved by using a telecentric scanning lens, which eliminates the perspective distortion, enables calibration of the *f*-Theta characteristics of the lens and, when colour-corrected, is a suitable solution for online inspection with scanning systems.

The lens designed by Sill Optics GmbH is colour-corrected for 1064 nm and for the entire visible range from 480 to 650 nm (Figure 2). Such lenses are quite expensive, but they enable online inspection and even measurement of the workpiece. The time saved during production amortizes the cost of the lens within hours of use. □

Contact: Konrad Hentschel, Sill Optics GmbH & Co. KG; fax: +49 9129 9023 23; e-mail: konrad.hentschel@silloptics.de; or circle 121.