Title: COARSE AND FINE FOCUS MECHANISM FOR A DATA READER

Abstract: An optical system (10, 30, 40) having a laser diode module (12, 32, 42), a primary focusing lens (14, 34, 44), and a secondary compensation lens (16, 36, 46), the secondary compensation lens (16, 36, 46) being of significantly lower optical power than the primary focusing lens (14, 34, 44), the secondary compensation lens (16, 36, 46) being mounted on a movable lens mount (47) downstream of the primary focusing lens (14, 34, 44) such that the primary focusing lens (14, 34, 44) provides for coarse focusing of a light beam (20, 31, 41), and the secondary compensation lens (16, 36, 46) provides for fine focusing of a light beam (24, 35), the fine focusing being applied in place during assembly of the optical system (10, 30, 40).
BACKGROUND OF THE INVENTION

The field of the present invention relates to data reading devices such as for example bar code scanning systems or more particularly to focusing systems for data reading devices and bar code scanners. The invention is applicable to both stationary or handheld scanners.

In high performance bar code scanners, the focus accuracy is critical to meeting aggressive depth of field requirements. In most cases, illumination is provided by a laser beam generated by a laser module. Typically, the laser module is focused before it is installed in the scanner. The present inventors have recognized that this preset focus scheme has several disadvantages. First there is an error in focusing due to the equipment used to focus and measurement error. Then there is additional error because the module focus procedure measures simple beam parameters, such as beam diameter at a given intensity percentage, that are related to bar code resolution, but do not fully characterize the beam.

Once the laser module is focused, it is placed into an enclosure or scan chassis and the beam is transmitted through or reflected off other optical elements (e.g. folding mirrors, scanning elements, additional lenses, etc.). Each of these optical elements creates additional focus error. The present inventors have also recognized that these errors can be made worse by stresses caused by mounting them onto the chassis or enclosure.
In long range scanners, the focus error is much greater because the waist location is further away from the laser module and the laser lens focal length is shorter to increase the optical efficiency of the system. If no fine focus adjustment is available after the laser module is placed into the scan chassis, the variation in read range would be unacceptable.

In previous bar code scanners, this fine focus has been done by refocusing the laser lens in the scan chassis. While this refocusing is possible, the sensitivity to lens movement is very high so the operation is difficult and time-consuming.

Thus the present inventors have recognized a need to address the issue of optical system focus error and sensitivity to focus adjustment of the laser lens and to perform a focus measurement that more accurately represents the scanner performance.

SUMMARY OF THE INVENTION

The present invention is directed to an optical system in which the light source, such as a laser diode module, includes a primary focusing lens and a secondary compensation lens. Together, these lenses make up a zoom system that allows coarse and fine focusing of the scanner in the production process.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic of an optical system according to a first embodiment;

Fig. 2 a schematic of an optical system according to a first embodiment;
Fig. 3 is a schematic three-dimensional view of the lens systems of Figs. 1-2;
Fig. 4 is a three-dimensional view of a lens barrel system according to a preferred embodiment;
Fig. 5 is a cross sectional view of the lens barrel of Fig. 4;
Fig. 6 is a schematic of a scanning system employing the lens barrel of Figs. 4-5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments will now be described with reference to the drawings.

Fig. 1 is a schematic of a first optical system comprising a light source such as for example a laser diode and a plurality of focusing elements. The focusing elements include a first lens and a second lens, the second lens having significantly weaker, though in this embodiment still a positive, optical power. The second lens is placed beyond (i.e. downstream of) the first lens in a mount such that the second lens can be easily translated relative to the laser diode and first lens. A translation mechanism is set forth in more detail below with respect to Figs. 4-5. Together, these lenses form a zoom system that allows coarse and fine focus. For clarity, the first lens may be referred to as a primary lens and the second, weaker lens may be referred to as a compensation lens. The final aperture is positioned downstream of the compensation lens.

As may be seen in Fig. 1, the beam downstream of the primary lens is still expanding, thus the primary lens does not fully focus or collimate the beam produced by the laser diode. The compensation lens is positive
power, completing the focusing of the beam, collimating the beam 24 to a given waist.

Figs. 2-3 are schematics of a second optical system 30, Fig. 2 being diagrammatic and Fig. 3 being three-dimensional. The system 30 comprises a laser diode 32 and a plurality of focusing elements. The focusing elements include a primary lens 34 and a negative power compensation lens 36 having a significantly weaker/lower optical power that is placed beyond the primary laser lens 34 in a mount that can be easily translated relative to the laser 32 and primary lens 34. A translation mechanism is set forth in more detail below with respect to Figs. 4-5. Together, these lenses 34, 36 form a focus adjustable, zoom system that allow coarse and fine focus.

The compensation lens 36 having negative power may have several advantages. First, the overall length of the zoom system should be minimized to conserve space. Second, the optical efficiency of the system should be maximized. If the compensation lens has positive power and is weaker than the primary lens as in system 10 of Fig. 1, the beam 22 hitting the compensation lens will be larger than it is exiting the primary lens (See Fig. 1). The area of the beam that is filled represents the optical efficiency of the system.

The negative compensation aspect is illustrated is Fig. 2 wherein the primary lens 34 has sufficient optical power to fully focus or collimate the beam 31 produced by the diode 32, i.e. the beam 33 downstream of the primary lens 34 is reducing toward a waist. The compensation lens 36 has negative power, but is not of such negative power (when placed at sufficient distance from the primary lens 34) to reverse the collimation as the beam 35 exiting the compensation lens 36. Thus the compensation lens 36
completes the focusing of the beam 33/35, continuing to collimating it, albeit at a reduced rate, to a given waist.

When the compensation lens 36 has negative power as in the system 30 of Fig. 2, a higher percentage of the beam is passed through the aperture 38 resulting in higher efficiency.

The sensitivity to focus movement is approximately proportional to the square of the ratio of the optical power of the compensation lens to the optical power of the primary lens. For example, if the primary lens has an effective focal length of 3.0mm and the compensation lens has an effective focal length of -27mm. The focus displacement required to move the waist by 2.5 cm (1 inch) using the primary lens, is 1µm (0.000039 inch). The focus displacement required to refocus the waist to the original location, using the compensation lens, is -110µm (-0.0043 inch). In this example, the sensitivity of movement of the focal point by position adjustment of the secondary lens is 1/100th that of the primary lens. Thus the sensitivity or accuracy of the mechanism required to move the secondary lens in order to make a desired fine focusing adjustment is greatly reduced.

In another preferred example, the primary lens has a EFL (effective focal length) of 3.3mm and the compensation lens has an EFL of -45mm. The EFL of the compensation lens is preferable 10x to 15x the EFL of the primary lens.

Figs. 4-5 illustrate an adjustable lens barrel system 40 including a laser diode 42 producing a laser beam which is focused first by a primary lens 44 and then by a compensation lens 46. The focused beam is then passed through an aperture 48 and out the module 40. The primary lens 44 is mounted within the primary lens barrel 45. The
laser diode 42 and primary lens barrel 45 are fixed in the
barrel housing 43. The compensation lens 46 is mounted in
the compensation lens barrel 47. The aperture 48 may be
incorporated into the compensation lens barrel 47 downstream
of the compensation lens 46 as shown. The compensation lens
barrel 47 is constructed to slide within the primary lens
barrel 45 thereby providing adjustment for the distance
between the primary lens 44 and the compensation lens 46.

Once the focus adjustment process has been completed,
the lens barrels 45, 47 are preferably locked in place by a
suitable mechanism to ensure that lens position does not
shift inadvertently during movement of the scanner. For
example, the tolerance fit between the compensation lens
barrel 47 and the primary lens barrel 45 may be such that a
friction fit is established to sufficiently lock the
elements in place after focal adjustment has been completed.

In a fabrication process, a tool is made to grasp the
end of the barrel 47 to provide for the fine adjustment of
the compensation lens 46 position after the unit 40 has been
installed in the scanner chassis. Optionally, a small motor
may be installed between the primary lens barrel 45 and the
secondary lens barrel 47 for actuating the fine position
adjustment of the compensation lens 46.

Alternately, the primary lens module 45 may be axially
adjustably mounted within the housing 43. In the
fabrication process, a course focus may be set first by
adjusting the position of the primary lens 44, providing a
course, approximate focus, and then effecting a fine focus
by adjusting the position of the compensation lens 46.

As to any of the above embodiments, the compensation
lens 16, 36 can compensate for the collimating error created
by the primary lens 14, 34. The compensation lens 16, 36
may also compensate for the collimating error over scanner components and process variation resulting in higher production yields and more consistent scanner performance.

It is desirable to perform the fine focus adjustment after the laser module is installed in the scanner chassis. In this case, the fine focus will correct for all focus errors caused by any element in the optical system. One way to determine optimal focus involves characterizing the optical beam (i.e. determining beam shape and size at a certain distance) by (1) measuring the beam diameter at a certain intensity level at a certain distance from the scanner and then (2) adjusting the position of the compensation lens 16 or 36 so that the spot size meets a given design requirement corresponding to that distance.

Though this method does not take into account differences in beam shape and signal processing electronics, the fine focus system facilitates the desired focus adjustment.

Fig. 6 is a schematic of a scanning system 50 employing the focusing system 10, 30, or 40, the lens barrel system 40 of Figs. 4-5 being illustrated. The system 50 may comprise a fixed scanner or a hand-held portable scanner. In the system 50, the lens barrel housing 40 is mounted to a base or chassis 52. The laser diode 42 produces a laser beam 41, focused by one of the lens configurations and methods embodied described above, which passes through a central portion of collection lens 54. The beam 41 is directed onto a scanning mechanism, in this embodiment a rotating polygon mirror 56, which scans the beam 41 across an array of pattern mirrors 58, 60 which in turn direct a plurality of scan lines into the scan volume. Return light is retro-directionally collected back from the pattern mirrors 58, 60 and back off the rotating polygon mirror 56 where it is
collected by collection lens toward fold mirror 62 which directs the focused return light onto a detector 64. The detector 64 converts the return light signal into an electrical signal which in turn is sent to the processing circuitry on the printed circuit board 66 where the electrical signal is processed.

The fine focus of the compensation lens 46 in the lens barrel system 40 may be accomplished in place within the scanning system 50 thus allowing for fine focus adjustment to compensate for focus errors in the optical components or their alignment, or in the signal processing.

This focusing adjustment system may be used with nearly a complete scanner thereby maximizing the number of scanner components in place when the focus adjustment is implemented, essentially adjusting for focus errors from any components of the optical system. Optionally, the focusing adjustment system may be accomplished or verified by scanning bar code labels thereby incorporating the signal processing system into the fine focus adjustment scheme.

Including effects of signal processing when adjusting the fine focus may be advantageous.

Thus the present invention has been set forth in the form of its preferred embodiments. It is nevertheless intended that modifications to the disclosed scanning systems may be made by one skilled in the art without altering the essential inventive concepts set forth herein.
What is claimed is:

1. A data reading device comprising
   a light source generating a light beam along an outgoing optical path;
   a primary lens disposed in the optical path for providing a course focus for the light beam;
   an axially movable lens mount;
   a secondary lens mounted on the movable lens mount and disposed in the optical path downstream of the primary lens, the secondary lens being of significantly lower optical power than the primary lens,
   wherein the secondary lens is axially adjustable via the movable lens mount for providing a fine focus control for the light beam.

2. A data reading device according to Claim 1 wherein the secondary lens comprises a negative power lens element.

3. A data reading device according to Claim 1 wherein the secondary lens comprises a positive power lens element.

4. A data reading device according to Claim 1 wherein the secondary lens has an effective focal length of between 10 times and 15 times the effective focal length of the primary lens.

5. A data reading device according to Claim 1 further comprising a primary lens barrel, the primary lens being mounted therein;
a secondary lens barrel, the secondary lens being mounted therein,
wherein the secondary lens barrel is axially adjustably mounted onto the primary lens barrel.

6. A data reading device according to Claim 1 wherein the light source comprises a laser diode.

7. A data reading device according to Claim 6 further comprising a housing for mounting of the laser diode and the primary lens barrel, wherein the primary lens barrel is axially adjustable relative to the housing for permitting a course focus adjustment.

8. A data reading device according to Claim 6 further comprising
   a chassis, wherein the laser diode, the primary lens, and the movable lens mount for the secondary lens are mounted on the chassis;
   a scanning mechanism disposed in the optical path downstream of the secondary lens,
   wherein the secondary lens is axially adjustable via the movable lens mount in place on the chassis.

9. A data reading device according to Claim 8 further comprising
   a detector for detecting return light signal and producing an electrical signal corresponding thereto;
   a signal processor for processing the electrical signal from the detector.
10. A method of assembling a data reader comprising the steps of:

mounting a laser diode in position to direct a laser beam along an optical path;

installing a primary lens in the optical path;

installing a secondary lens in the optical path downstream of the primary focusing lens, the secondary lens having a significantly lower optical power than the primary optical lens;

focusing the laser beam to an approximate focus position by positioning the primary lens;

focusing the laser beam to a fine focus position by adjusting position of the secondary lens.

11. A method according to Claim 10 wherein the secondary lens comprises a negative power lens element.

12. A method according to Claim 10 wherein the secondary lens comprises a positive power lens element.

13. A method according to Claim 10 further comprising providing the secondary lens with an effective focal length of between 10 times and 15 times the effective focal length of the primary lens.

14. A method according to Claim 10 further comprising mounting the primary lens in a primary lens barrel;

mounting the secondary lens in a secondary lens barrel;

mounting the secondary lens barrel in the primary lens barrel such that the secondary lens barrel is axially adjustably mounted in the primary lens barrel.
15. A method according to Claim 10 further comprising providing a scanning mechanism for scanning the light beam;
mounting all optical components within a scanner housing wherein the step of focusing the laser beam to a fine focus position by adjusting position of the secondary lens is accomplished with the optical components mounted in place within the scanner housing.

16. A method according to Claim 10 further comprising detecting return light signal with a detector, the detector producing an electrical signal corresponding thereto;
processing the electrical signal from the detector.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7): G06K 7/10
US CL: 235/454, 462.22, 462.23, 462.42
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S.: 235/454, 462.22, 462.23, 462.42

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>A</td>
<td>US 5,870,133 A (NAIKI) 09 February 1999 (09.02.1999), see entire document.</td>
<td>1-16</td>
</tr>
<tr>
<td>A,P</td>
<td>US 6,068,190 A (SHEPARD et al) 30 May 2000 (30.05.2000), see entire document.</td>
<td>1-16</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

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