

Revision:2

**Application Letter 12**

**Comparison of Confocal  
Single-Mirror and Two-Mirror  
Point Scanners**

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## Note

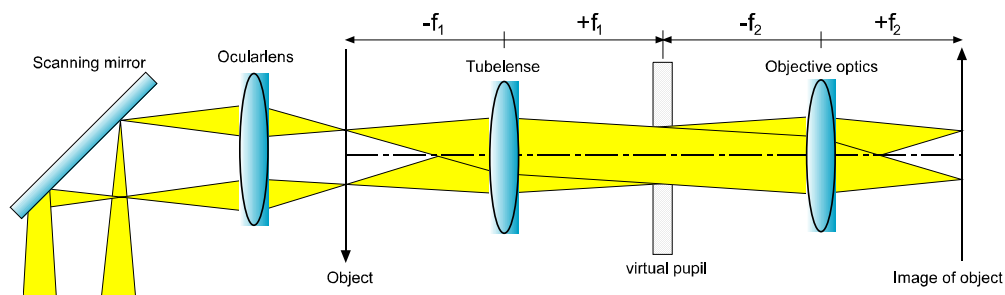
This Application letter is also available on Leica Lasertechnik's home page [www.llt.de](http://www.llt.de)

## 1. Confocal Single-Mirror Point Scanner

Using confocal single-mirror point scanners, the surface of a sample is scanned by the minute focused light spot of a laser beam. The movement of the laser beam in raster pattern is made possible by a cardanically suspended mirror which is rotatable along two axes. A high-frequency galvanometer (x-galvanometer) moves the mirror along the first axis (x-axis). Thus the focus of the laser beam describes a line. Both the mirror and x-galvanometer are positioned on the axis of a second, larger galvanometer (y-galvanometer). At the end of each line the y-galvanometer moves the mirror together with the x-galvanometer along an axis (y-axis) which is perpendicular to the x-axis. By the concerted movements of both galvanometers the mirror directs the laser beam along lines across the sample.

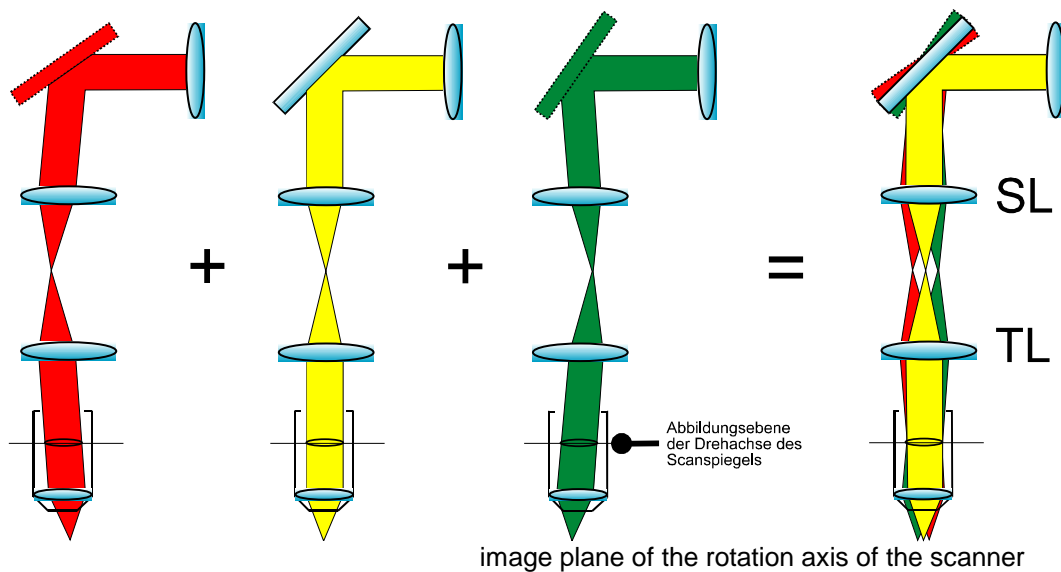
### 1.1 Function and Construction of the Single-Mirror Arrangement

A single-mirror point scanner ensures that both rotation axes are imaged in the so-called entrance pupil, provided the optics are properly calculated. With this telecentric imaging the laser scanning beam has a rotation point in the entrance pupil. The illustration below depicts this kind of optical imaging.



**Figure 1: Schematic illustration of a telecentric optical arrangement**

The entrance pupil is a reference plane for designing the objective. The light entering via the virtual entrance pupil forms an optimum image in the objective. This shows how closely the development of confocal optics is interrelated with the development of objectives.



**Figure 2: Projection of the scan mirror surface into the entrance pupil of the objective**  
 SL = scan lens, TL = tube lens

Single-mirror point scanners make optimum use of the objective, as they enable that the complete scan range of the mirror is projected into the entrance pupil of the objective. The laser scanning beam precisely moves in the focal plane of the objective.

## 1.2 Advantages of the Single-Mirror Arrangement

1. Optimum use of the objective without edge shadings or image distortion.
2. Precise movement of the laser scanning beam in the focal plane of the objective.
3. Both rotation axes are always projected exactly into the mirror thus pincushion distortions cannot occur.
4. Intensity 2% higher than that of two-mirror scanners

## 1.3 Disadvantages of the Single-Mirror Arrangement

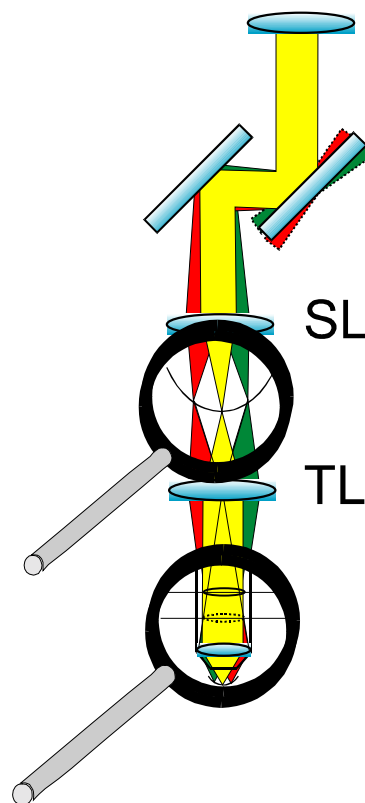
1. With rotating the image plane (rotatable scan range) by correspondingly programming the scan movement the performance would be determined by the slower rotation axis. Thus the scanning process is considerably slower than with a non-rotatable scanner.

## 2. Confocal Two-Mirror-Point Scanner

Confocal two-mirror point scanners scan the surface of a sample by means of the focused light spot of a laser beam. The movement of the laser beam is actuated by two independently movable mirrors (x-mirror, y-mirror). One galvanometer (x-galvanometer) tilts the mirror along the first axis (x-axis). Thus the focus of the laser beam describes a line. A second galvanometer (y-galvanometer) moves the light beam coming from the x-mirror in y-direction. Owing to the combined movements of the galvanometers the mirrors direct the laser beam along lines across the sample. The scan range is free rotatable by corresponding programming.

### 2.1 Function and Construction of the Two-Mirror Arrangement

The diagram below depicts the effects of moving one of the two scan mirrors.

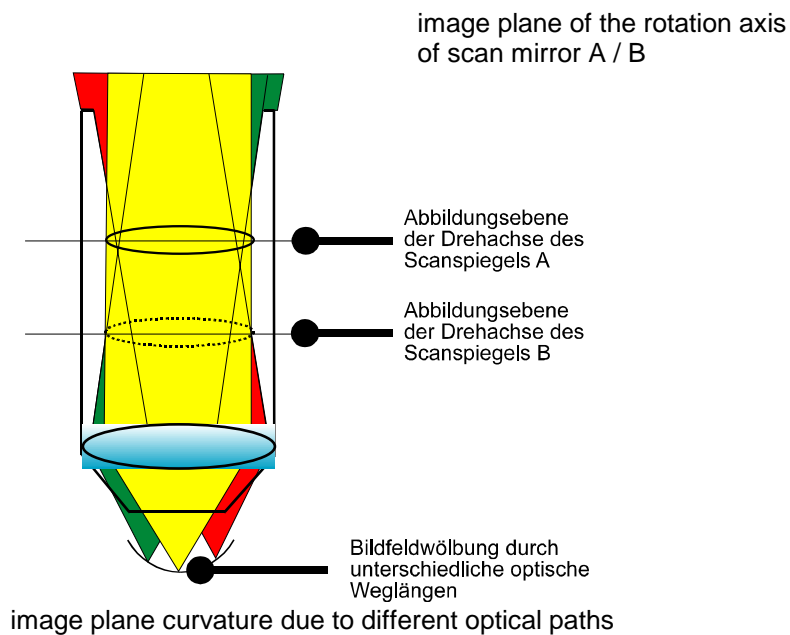


**Figure 3: Artefacts occurring with two-mirror point scanners**

Rotations of the mirror, which is in the farthest position to the objective, deflect the incident light beam. In particular in case of larger deflections the light beam is no longer projected exactly onto the rotation axis of the second mirror.

This leads to geometrical image distortions, whose characteristics are known but which can only be compensated for by recalculations. Relevant insights are given in the scientific publication of Jean Montagu (Jean Montagu, *Two axis beam steering systems*, TABS, SPIE Vol. 1920, proceedings reprint, pp. 162-173).

The ultimate scan mirror (below called scan mirror B) projects an image through the whole optics to a position in the objective different to that of the first mirror. The image plane of mirror B lies outside the entrance pupil of the objective. Thus the neutral position of the moving laser scanning beam is out of the optimum telecentric plane. The result is the occurrence of further artefacts.



**Figure 4: Different image planes of the two scan mirrors**

In case of such a shifting of the telecentric plane the objective is no longer completely illuminated, which results either in resolution losses or considerable light losses.

This effect can only be compensated for by increasing irradiation of the rear objective lens. Opening the illumination diameter yet reduces the light intensity. Owing to this compensation the light of weak laser sources loses its effect on the sample very rapidly.

The shifting of the telecentric plane can be evaluated very easily. The distance between the two scan mirrors is projected into the objective by the magnifying factor of the lens combination scan lens+tube lens.

The magnifying factor follows from the ratio of focal length of the scan lens and focal length of the tube lens:

$$V = A \cdot \left( \frac{f_{SL}}{f_{TL}} \right)^2$$

V = Resulting shifting of the telecentric plane in mm

A = Distance in mm between the two scan mirrors

$f_{SL}$  = Focal length of the scan lens

$f_{TL}$  = Focal length of the tube lens

Some two-mirror point scanners are designed in such a way that the geometrical rotation axis of the two mirrors lies in the middle of the them. Thus the telecentric planes of the two mirrors are positioned symmetrically around the entrance pupil. This layout is a compromise for both mirrors.

## **2.2 Advantages of the Two-Mirror Arrangement**

1. Free rotatable scan range within the sample.
2. Faster scanning of smaller image fields is possible, if galvanometers of low mass are used.
3. It is possible to carry out a so-called Noodle-Scan, i. e. very rapid scanning within defined ranges.

## **2.3 Disadvantages of the Two-Mirror Arrangement**

1. Image distortions due to the different spatial positions of the rotation axes.
2. The distance between the two scan mirrors is magnified by the optics and shifts the telecentric plane(s) out of the entrance pupil. This leads to edge shadings and resolution losses. These effects can only be compensated for by increased irradiation of the entrance pupil. Increased irradiation is yet not applicable in particular when using objectives with low magnification and large pupil diameter, since otherwise no satisfying results are obtained with high magnifications (and small pupil diameters). In this case artefacts occur more frequently. Thus the used intensity of weak lasers is further reduced. In general a compromise has to be found between resolution loss (due to numerical aperture) and light loss (due to increased irradiation of the entrance pupil).
3. Slightly increased losses owing to the second mirror.