

## Twin Rod Birefringence Compensation

The advantages of a twin rod, birefringence compensated architecture in high average power pulsed Nd:YAG lasers: much improved spatial profile, extraction efficiency and harmonic conversion efficiency.

Strain birefringence is a thermal effect in Nd:YAG brought about by heat deposited in a rod by pumping it. The centre of the rod becomes warmer than the outside, leading to thermal strain as the centre expands, creating tension at the edge. Because of this, light polarized along a radius of the rod aperture sees a different refractive index compared to light polarized tangentially. In effect, each point in the rod aperture becomes a wave-plate with its fast and slow axes respectively in radial and tangential directions. This difference becomes greater nearer the outside of the rod. The greater the heat input, the greater the difference; thus high energy, high repetition rate flashlamp pumped lasers exhibit the most strain birefringence.

It can be seen then that a horizontally plane polarized beam passing through a rod exhibiting such birefringence becomes depolarized and that the effect is strongest nearest the periphery and along axes at 45 degrees from the plane of polarization. Upon returning back through the rod, the effect is doubled and the vertical components of the depolarized beam are rejected by the intracavity polariser, which forms part of the Pockels cell. This leads to the 'Maltese cross'

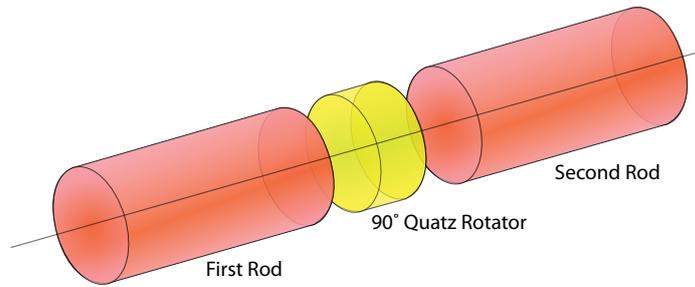
shape typical of high average power single rod Nd:YAG lasers. The energy loss, as much as 30%, and the distorted beam profile limit the usefulness of high average power single rod lasers.

A twin rod, birefringence compensated design works by compensating the birefringence in one rod against the other. To achieve this in an oscillator, two rods are used and the polarization of the beam emerging from one rod is rotated through 90 degrees before passing through the next. Thus the component of light that was polarized along a 'fast axis' at any point in one rod is polarized along a slow axis in the next and vice versa. The net result is that the total depolarisation in the beam is a result of the difference, not the sum, between the birefringence in the two rods.

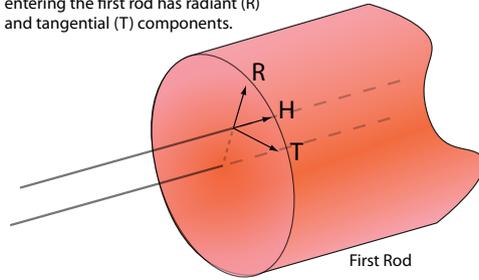
This method is only perfect if the birefringence characteristics of both rods are identical. In reality this is not the case but in practice this technique works well for lamp pumped Nd:YAG rods used close to their storage limit for energy and at frequencies up to 200Hz.

This compensation technique is also applied to amplifiers. Although the spatial profile is not affected by strain birefringence in the amplifier rods, compensation improves harmonic conversion efficiency and other optical phenomena dependent upon a high degree of plane polarization.

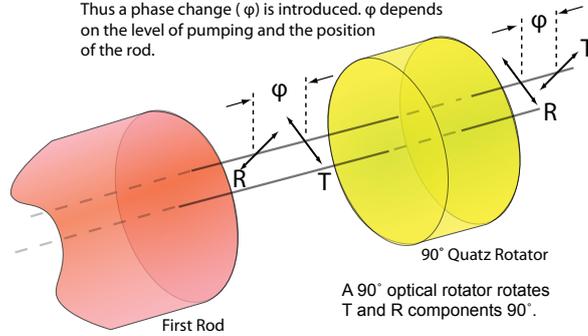
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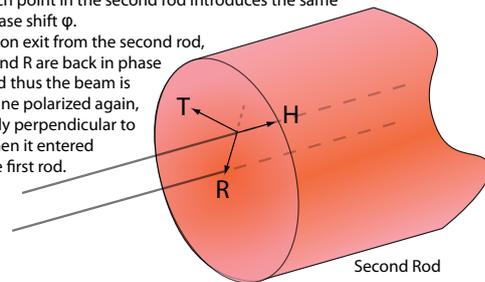
**1** Horizontally polarised light (H) entering the first rod has radiant (R) and tangential (T) components.



**2** In a pumped rod, the strain birefringence is a difference in refractive index for radial and tangential components. Thus a phase change ( $\phi$ ) is introduced.  $\phi$  depends on the level of pumping and the position of the rod.



**3** When entering the second rod, the T component is now radially polarized and vice versa. Each point in the second rod introduces the same phase shift  $\phi$ . Upon exit from the second rod, T and R are back in phase and thus the beam is plane polarized again, only perpendicular to when it entered the first rod.



**4** Radial and tangential components are now in phase. Without compensation, the phase shift would be  $2\phi$ .

