

# Power Scale-Up in Good Beam-Quality Radially-Polarized Rod-Based Lasers

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In this work we present a path to scale-up in the power of good beam-quality radially-polarized solid-state lasers. Beam-quality degradation and depolarization must be minimized in the power amplifier chain. We present the performance of our power amplifier module that add >1.5 kW to the laser beam with only a very low beam-quality degradation of  $\Delta M^2=1.5$  and with excellent polarization maintenance.

High-average-power solid-state lasers are important in many applications. High-power, radially-polarized beams are of particular interest due to their advantages in material processing [1]. Rod-based lasers, which are simple and low cost, can take advantage of radial polarization to bypass thermally induced birefringence, which is the most serious beam-quality degradation factors in rod-based lasers, so as to obtain good beam quality [2, 3].

Radially-polarized oscillators of several 100s Watts have been demonstrated in the past with excellent beam-quality and polarization purity. Power scaling to the kW regime requires power amplifiers that may scale-up the power with minimum beam quality deterioration and polarization distortion. In this work we analyze the main requirements from power amplifiers to be suitable for scaling up the output power and demonstrate a basic amplification block that meet these demands.

Maintaining beam-quality and polarization encounter three main factors: 1. Radially symmetric optical aberrations, 2. Non-radially symmetric optical aberrations, and 3. Non-radially symmetric strains. Radially symmetric aberrations are the strongest degrade beam quality degradation factor, but it do not depolarize radially-polarized beams and could be compensated using a wave-front correcting elements or by utilizing the spherical aberration induced by spherical lenses. A more serious factor is the effect of non-radially symmetric pump-distributions on radially-polarized beams. Non-radially symmetric aberrations induce beam quality degradation and depolarization as well. Depolarization induced during beam propagation while the wave-front deformation breaks the radial symmetry of the intensity distribution and degrades the radial polarization purity. This effect may be eliminated along the amplifier chain by relay-imaging the amplifiers modules, or by using a specially designed wave-plate correctors. The weakest effect but the hardest to correct is the birefringence induced by non-radial, thermo-mechanical strains. When the pump-distribution is not radially-symmetric, the birefringence tensor will possess radial-azimuthal coupling terms, which causes depolarization of radially polarized beams. This effect was analyzed analytically and experimentally and has proven to be a strong factor that degrades the beam quality in long amplifier chains.

In order to further our scale-up effort, we have developed a basic amplification module based on a pump chamber that creates a near-perfect radially-symmetric pump-distribution that requires correction of only low-order spherical aberration. Our latest results using these pump chambers demonstrate power scalability with excellent beam quality preservation and negligible depolarization. We intend to use these pump chambers in order to scale-up the power of our laser system and to produce multi-kWs of power in a radially-polarized, low-aberration beam.

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