

Tapered Amplifiers

For amplification of seed sources
or for external cavity laser setups

755 – 1064 nm

m2k *Laser*

High-Brightness Diode-Lasers

The Tapered Laser Concept

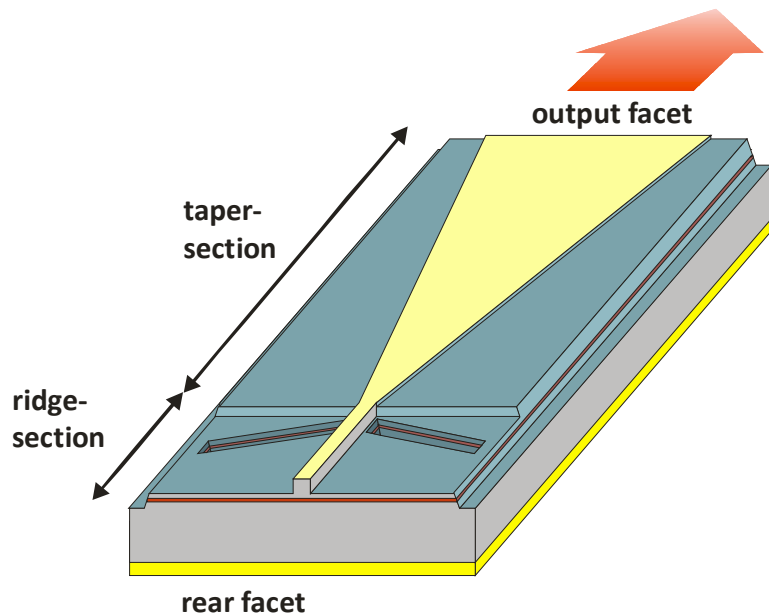
Diode lasers with tapered design combine a nearly diffraction limited beam quality with output powers which have previously only been available for diode lasers with broad-area design. They can be used either as stand-alone high-brightness diode lasers or as an amplifier within a MOPA (Master Oscillator Power Amplifier) or ECL (External Cavity Laser) configuration. In comparison to pure single-mode or broad-area lasers, laser systems based on tapered amplifiers offer not only high power and nearly diffraction limited beam quality, but also tunability and extremely narrow line widths.

To achieve these characteristics, the lateral design of the diode consists of two sections monolithically integrated on one chip. High beam quality is made possible via an index-guided ridge-waveguide or MESA structure. In contrast, high output power requires a gain-guided broad pumped area with an output facet width of several 100 micrometer, which leads in summary to a taper section.

The beam quality depends on the beam waist and the far field of the laser. In vertical direction the beam quality of a diode laser is typically diffraction limited caused by the used semiconductor layer sequence. Because of the tapered geometry, the minimal lateral beam waist in the focus depends on the width of the ridge waveguide section, not on the width of the output facet. In comparison to broad-area lasers with identical output power this leads to a beam width reduced by a factor of 20-30. The lateral far field is given by the taper angle. By stretching the length of the taper section the output facet will

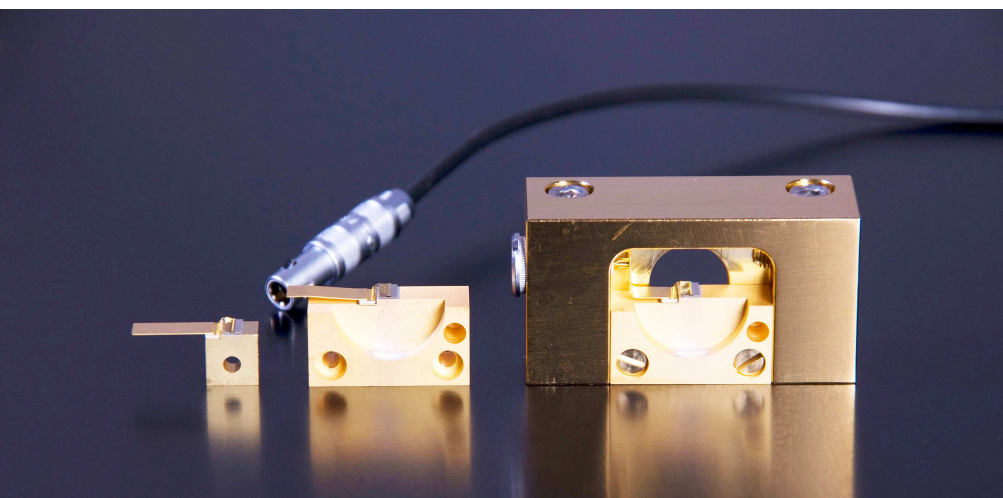
be broadened and the output power can be increased up to several Watts. The minimal beam width and the far field will remain maintained and therefore the beam quality does not change.

The ridge-waveguide and taper sections are processed cost-effective by using standard diode laser processing steps like optical lithography and a mix-



ture of dry and wet chemical etching. The structure consists of a taper angle of 4° or 6° together with a taper section length of 2mm or 4.3mm. This leads to different emitting aperture widths of $205\mu\text{m}$ or $256\mu\text{m}$. The ridge width is typically $3\mu\text{m}$. The ridge height is chosen appropriately for the propagating wave to fill the taper angle. Cavity-spoiling grooves on both sides of the ridge section suppress undesired Fabry-Perot modes.

More than 15 years ago, powerful tuneable diode laser systems based on tapered amplifiers have been developed for the first time. M2k has introduced its first commercial tapered amplifier for amplifying seed lasers in 2001. A few years later tapered amplifiers for external cavity systems have been added. Nowadays tapered lasers become even competitive to broad-area lasers for some applications because they allow avoiding some limitations of broad-area laser designs.



Tapered Amplifiers

Tapered amplifiers used in MOPA configurations

MOPA setups are used for the amplification of an existing seed laser. The seed power between 15mW and 50mW can be amplified up to nearly diffraction limited power values of more than 2000mW.

A typical setup (1) consists of a seed laser, e.g. a grating stabilized ridge laser or a DFB laser, an optical isolator to avoid back-reflections between seed laser and tapered amplifier, a half wave plate to adjust the polarization between seed laser and tapered amplifier and a focusing lens in front of the rear facet of the tapered amplifier. The waveguide of the ridge-section of the tapered amplifier acts as a slit to capture the light of the seed laser. Then the light will be amplified in the tapered section without losing its spectral or spatial quality.

For the quality of the MOPA setup it is essential that both facets of the tapered amplifier are highly antireflection coated with values of less than 0.01% to avoid laser action of the amplifier chip itself.

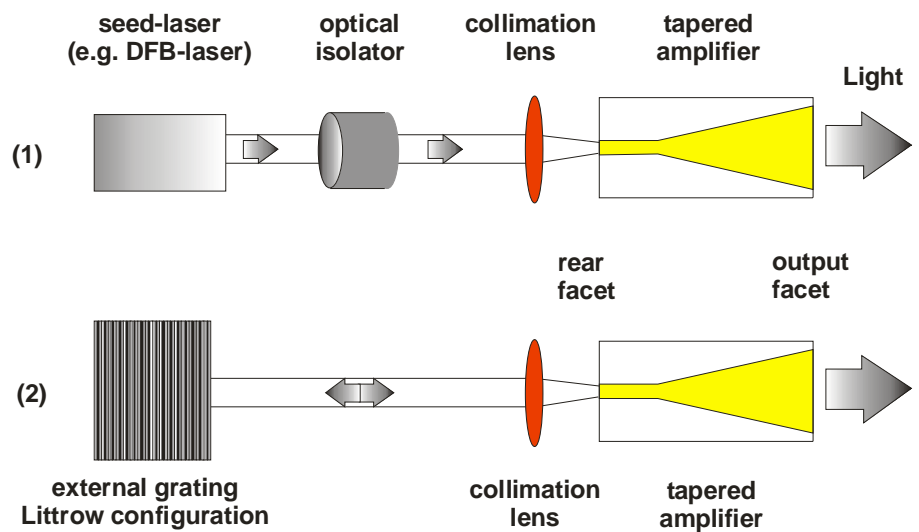
Tapered amplifiers used in external cavity setups

Tapered amplifiers can be also used in external resonator laser configurations to combine tuneable nearly diffraction limited output powers of more than 2000mW with small spectral line widths and high side mode suppression ratios. No additional seed laser and extra electronics is needed which makes it attractive for applications where cost plays an important role.

For example a typical external cavity setup (2) in Littrow configuration consists of a tapered amplifier with a collimating lens in front of the rear facet, a half wave plate to correct the polarisation and an external grating. The first order of the dispersed light is reflected back into the ridge side of the tapered amplifier. The waveguide acts as a slit to capture a small part of the light at the lasing wavelength which is used to seed the ridge section and then be amplified

in the tapered section. The front side is coated such that a small amount of the light is reflected back to provide oscillation.

In comparison to tapered amplifiers in MOPA configuration the rear facets here are provided with a highly anti-reflection coating of less than 0.01% to guarantee good coupling to the grating. The front facets are provided with an anti-reflection coating in the range of 1% to protect the chips from back reflections.



Characteristics

- different amplifiers between 755nm and 1065nm available
- amplification of seed lasers up to 2000mW
- highly antireflection coatings of <0.01%
- nearly diffraction limited behaviour, typ. $M^2 < 1.5$
- ASE suppression >40dB
- typically 20-40nm tuning range

Applications

- laser cooling and trapping
- Bose-Einstein condensation
- metrology
- Raman spectroscopy
- absorption spectroscopy of atoms, molecules and ions
- frequency doubling
- interferometry
- optical pumping

Specifications

Detailed data sheets for each wavelength can be downloaded at www.m2k-laser.de

Spectral data				
Usable wavelength range	755 - 775nm 790 - 810nm	779 - 790nm 845 - 865nm	935 - 965nm 1040 - 1064nm	865 - 900nm 940 - 985nm 1000 - 1025nm
ASE suppression	>40dB			
Beam parameter output facet				
Output aperture at front side	205µm	256µm	205µm	256µm
Divergence parallel (95% power included)	17	10-12	17	10-12
Divergence perpendicular (95% power)	45	50	65	50
M ² (1/e ²)	<1.5 @ 1.0W <1.6 @ 1.5W <1.7 @ 2.0W			
Astigmatism	depends on operating conditions			
Electrical data				
Typical operation current with feedback	<2.0A@0.5W <3.0A@1.0W	<3.0A@1.5W <3.5A@2.0W	<2.0A@0.5W <2.5A@1.0W	<3.0A@1.5W <3.5A@2.0W
Maximum current with feedback	3.0A	3.5A	3.0A	3.5A
Maximum current without feedback	2.0A			
Operation voltage	<1.8V	<1.8V	<1.6V	<1.7V
Polarisation	TM	TM	TE	TE
Thermal data				
Operating temperature	15 ... 30°C			
Recommended heat sink temperature	20 ... 25°C			
Storage temperature (non-condensing atmosphere)	-20 ... 60°C			
Operating environment conditions	non-condensing atmosphere			
Package				
Heat sink type	c-mount, DHP-inset (DHP-I) or DHP-frame (DHP-F)			
Cavity length	2000µm	4300µm	2000µm	4300µm
Cathode (-)	wire flag			
Anode (+)	base plate			
Options				
Heat sink types	c-mount, DHP-inset (DHP-I) or DHP-frame (DHP-F)			
Connector	customized connector cables for DHP-F available			

Safety

This is a laser class IV product according to IEC - Standard International Commission (Publication 825, 1993). The laser light emitted from this laser diode is invisible and/or visible and is harmful to the human eye. The safety regulations for eye and personell protection included in the IEC Standard must be observed to avoid any harm to operating personell. Avoid direct exposure and looking into the laser diode, into the collimated beam or into the fiber when it is linked to the module.

Operation and handling

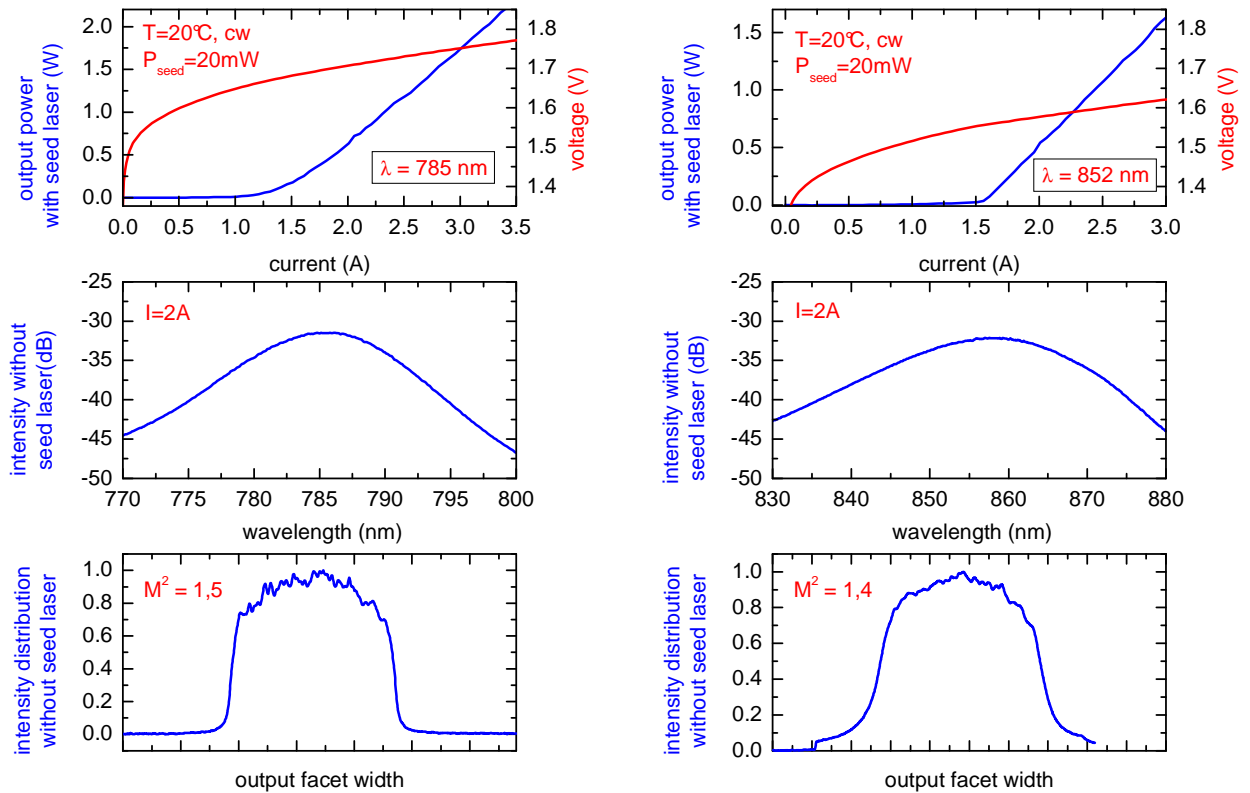
Diode lasers are extremely sensitive to over-voltage. Take extreme precaution to avoid electrostatic charges. Precautions against spiking during switching on and off the power supply must be assured. Correct polarity of power supply must be assured. During handling personell has to wear wrist straps. Grounded work surfaces and additional antistatic techniques are mandatory during handling. Device failure and safety hazard are caused by operation in excess of maximum ratings. Exceeding output power and temperature specification will result in accelerated device ageing.



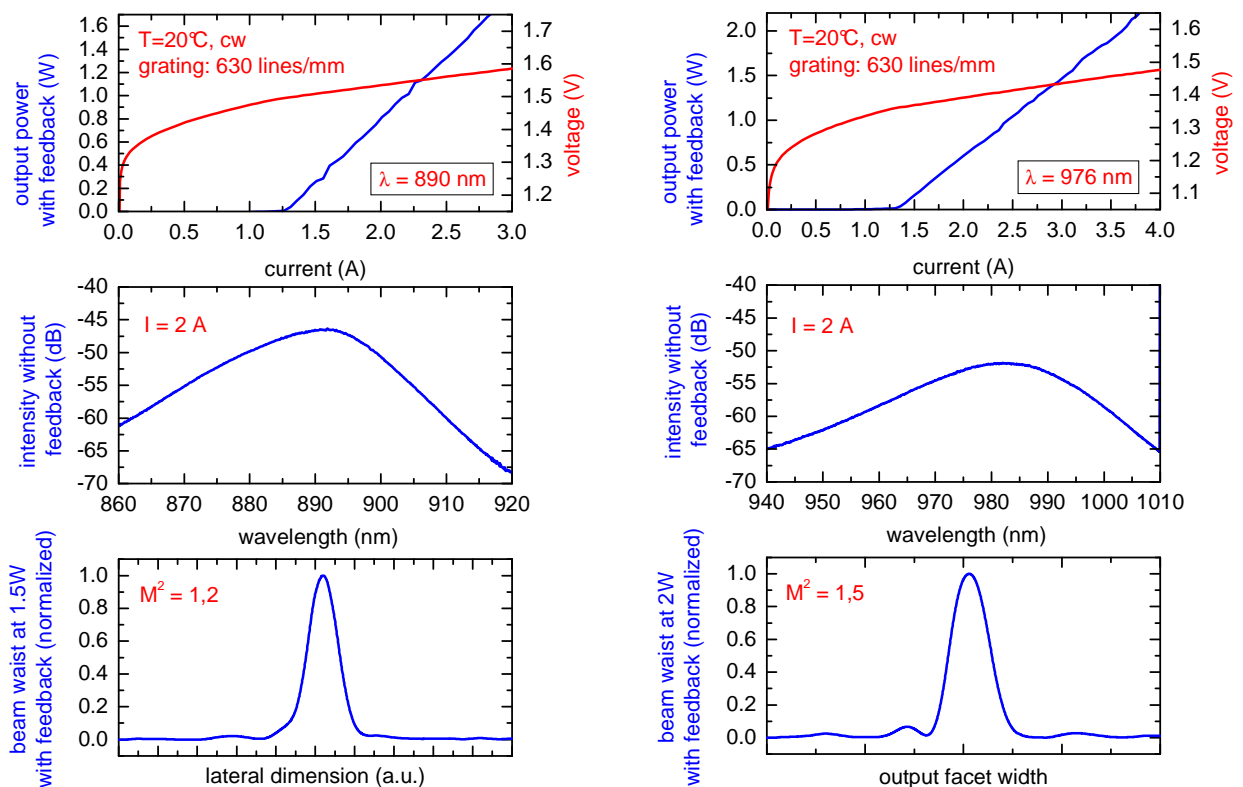
Example Measurement Data

The charts presented only describe typical measurement data examples. All tapered amplifiers are characterised individually, the results being contained in the documentation included. M2 has been measured using a commercial BeamScope in accordance to ISO 11146. The display options are subject to alteration by m2k-laser

Tapered amplifier used in MOPA configuration



Tapered amplifier used in external cavity configuration



m2k *L*aser

High-Brightness Diode-Lasers

Welcome at m2k-laser

Founded in 2001 by several member of the staff from the well-known Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg, Germany, m2k-laser is focused on the design, development and manufacturing of innovative high-brightness diode lasers. In 2007, m2k-laser became part of ROFIN-SINAR, which holds majority stake.

Our diode lasers undergo epitaxial growth at several multi wafer MBE systems for GaAs and GaSb in accordance to our in-house laser designs. Our core technology consists of clean room based complete process lines for diode lasers including a facet coating technology of our own. For this purpose, we can rely on the long-standing experience of our staff and on distinguished production technology.

We offer single emitters, laser bars and laser modules based on tapered, broad-area and ridge-waveguide designs. Our diode lasers in the near-infrared (750-1070nm) and mid-infrared (1.85-2.5 μ m) wavelength regimes are being used globally in the fields of medical treatment, materials processing, spectroscopy and metrology.



Imprint

m2k-laser GmbH
Hermann-Mitsch-Str. 36a
79108 Freiburg
Germany

Phone: +49-761-5158-7370
Fax.: +49-761-5158-7376
Email: info@m2k-laser.de
Web: www.m2k-laser.de

Editor-in-chief:
m2k-laser GmbH

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