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Frequency Doubling

Topics:
Interaction of Light and Matter
Crystal Optics
Non-linear Optics
Second Harmonic Generation
Phase Matching Condition
KTP Crystal
Nd:YAG Laser

Lasers which emit light in the short wavelength spectral range are expensive and not suffici economic way to generate such radiation is achieved by frequency doubling.
Especially the generation of green laser radiation is an important requirement of the lithograp is being replaced more and more by frequency doubled diode pumped Nd:YAG lasers. Th doubled light and the possibilities of non-linear optics learnt in this experiment will be explair is very important for laser technology, since the processes of the generation of short pulses the experiment, the phase matching condition will be presented and analysed. The efficiency of frequency doubling will be determined and hints for an optimized conversion rate will be evaluated in the experiment. For the first time, the frequency doubling can be followed up in a certain manner by a practical experiment. The theoretical understanding of the non-linear optics grows by practical verification to increased know how. Incidentally the understanding of birefringent crystals grows by experience of phase matching. The fundamental wave is generated by a diode laser pumped Nd:YAG laser with an open resonator structure. The non-linear crystal is placed into the resonator and intra-cavity SHG is carried out. The reflectivity of the output coupler of the Nd:YAG laser is chosen as high as possible to obtain several watts of power of the fundamental wave inside the cavity.

Examples of investigation and measurement

Basics
Non-linear optics is introduced by reference to a curved characteristic line as it is done in communication technology. From the distorted output signal, the fundamental wave as well as the harmonics of higher frequency are received by means of a Fourier transformation. In optics, frequency doubling is introduced as a parametric process for which the parameters like phase matching and high non-linearity of the crystal are discussed under the aspect of getting a high conversion ratio. Using the birefringent properties of the KTP - crystal, it is shown how the phase matching condition can be fulfilled. Since the generation of the fundamental wave is done by a Nd:YAG laser, this one is also described.

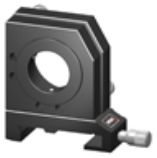
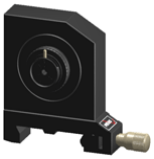
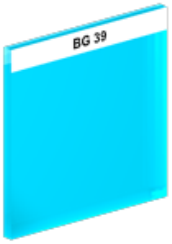
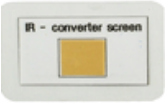
Characterisation of the diodelaser
The graphic representation on the right side can be plotted either point by point measurement of the power of the diodelaser and the injection current or by the use of the low frequency modulator (Module M). In the latter case an oscilloscope is used in the XY-mode. The X-channel is connected to the output of the injection current of the controller LDC-01 and the Y-channel to the output of the photo amplifier at the controller LDC-01. A standing picture of the function can be observed on the screen of the oscilloscope. The threshold current and the slope efficiency are, for instance, measured for different temperatures. By variation of the off-set different parts of the characteristic line can be selected to define the criteria for linear modulation. This gives the link to communication technology.

Output power of the Nd:YAG laser
Although a high reflectivity has been chosen for the resonator mirror (R>99.98%) about 10 to 20 mW of fundamental wave power (1064 nm) are transmitted to the outside of the resonator. If 0,5 % is accounted for the total losses, there will be 4 Watt as the fundamental wave power within the resonator. The function shown on the right can be plotted either point by point or by the use of the modulator. In the latter case, the photo detector is connected to the Y-channel and the injection current (respectively the power of the diodelaser) to the X-channel of the oscilloscope. Each modification of the parameters like temperature (wavelength of the diodelaser) or state of adjustment of the resonator mirror can directly be studied.

Power of the frequency-doubled radiation
By means of the filter BG39, which is placed in front of the photo detector, the frequency-doubled radiation is measured. A standing picture of the measured values is received on the oscilloscope in the same way as in the previous example. Filter BG39 is used instead of filter RG1000. In an illustrative way, the quadratic relation between the power of the harmonic wave and the power of the fundamental wave becomes evident. Depending on the state of adjustment and the cleanliness of the optical components, up to 3 mW (multimode) of „green“ power can be generated. By use of the option „1 Watt laserdiode“, the power can be increased to 10-15 mW.

Required Equipment

Cat. No.	Qty.	Description	Illustration
02.0502	1	**Profile rail OCM 650, 500 mm with ruler** The main components of the experimental systems are the optical rails OCM 650. They are manufactured distortion-free and are of thermally stabilized aluminium. The surface is electro-polished and black anodized. Because of the precise manufacturing, the smoothness deviation is less than 25 µm/m and the deviation of the symmetry axis of the rail is less than 10 µm/m, thus maintaining the optical axis during displacement of the carrier. The rail has a dovetail like profile. Gear racks can be inserted and fixed into the slots.	

02.2126	3	**Mounting plate OCM 650 for click 25** Mounting plates are used to hold optical mounts. A characteristic feature of the mounting plates is the “click” mechanism of the inserts based on spring loaded spheres. Snapping in the groove of the inserted click mount, the optical element is kept in an exact position. On the other hand, the system allows a quick and easy change of the mounted inserts. The mounting plates are made out of special anodized aluminum. Mounted onto the carrier 20 mm, the mounting plates can be placed onto an optical rail.	
02.2202	1	**Filter plate holder FH 650 for 3 filters 50 x 50 x 3 mm including carrier 30 mm** The holder can support a total of three filter plates with the dimension of 50x50 mm. The maximum thickness can be 5 mm. Lateral springs fix the filters within the holder. Round filters can be used by means of filter adapter.	
02.2526	1	**Target screen in 25 mm click mount** To align a light beam coaxial to the centre axis of the rail set-up this target is used as visual aid. It is mounted into a click 25 mm mount.	
02.5404	1	**Laser mirror adjustment holder right** with 1/2“ insert for LSF Laser mirror mounts and carrier 30 mm	
02.5406	1	**Laser mirror adjustment holder left** Same as 02.5404, however mounted as „left“ version, that means the mirror is opposite to the optical beam which is considered to travel from left to right. A combination of a right and left versions is always used to set-up an optical resonator, where the mirrors are oriented face to face.	
04.0030	1	**Focusing optic with triplet lens system, f=6 mm NA 0.6 mounted in click ring 25 mm** The collimator consists of a three-lens system with a short focal length (f=6 mm) and a large aperture in order to collimate the strongly divergent laser diode beam. It is mounted into a 25 mm click ring in such a way that the whole unit can be used in connection with a mounting plate (02.2126)	
04.0050	1	**Biconvex lens f=60 mm in click 25 mount** Different glass lenses are mounted onto a special anodized aluminum click mount 25 mm by two threaded mounting rings to be used in connection with a mounting plate (02.2126).	
04.0122	1	**RG 1000 Coloured glass filter** This filter suppresses radiation with a wavelength smaller than 1000 nm in such a way, that for instance the pump radiation of 810 nm is suppressed and the generated wavelength of 1064 nm of the Nd:YAG laser transmitted. It has characteristics like a high pass filter, a size of 50x50 mm and a thickness of 3 mm fitting into the filter plate holder (02.2202).	
04.0124	1	**BG 39 Coloured glass filter** In order to separate visible radiation (400 - 750 nm) from the above following wavelength (NIR), this filter is used. Commonly such a BG39 filter is used to remove residual pump power at 810 nm and fundamental laser radiation at 1064 nm from the second harmonic generated radiation at 532 nm. It has a size of 50x50 mm and a thickness of 3 mm fitting into the filter plate holder (02.2202).	
04.0302	1	**Infrared display card 0.8-1.2 µm** To convert invisible radiation in a wavelength range of 0.8-1.2 µm into visible light, this card is used. Depending on the incident power,	

the visible spot ranges from orange to white. This card can only be used for non-focused optical power up to 0.5 W.

04.0306 1 **Optic cleaning set**

Especially for optics used in connection with laser applications, cleaning the optic surfaces is a must for satisfying operation of the laser. For this purpose soft cleaning tissues wetted with pure aceton are used. To hold the folded tissues clamp pliers are provided. To store the leaning liquid, a bottle with dispenser top is provided. However, due to drug administration laws this bottle comes empty and the required aceton must be provided locally.

04.0486 1 **Nd:YAG rod in holder LSF 650 1/2" coated HT 810, HR 1064, HR 532 and AR 1064**

A Nd:YAG rod is mounted into a stress-free clamping disk which is inserted into the laser mirror holder LSF 650. The back side of the rod is coated for high transmission (HT) of the pump wavelength and high reflectivity (HR) for the lasing wavelength. To enhance the second harmonic generation, the backside provides also a high reflectivity at 532 nm.

04.0488 1 **Laser mirror SHG100**

The laser mirror holder LSF 650 is designed to accommodate sensitive Laser mirrors with a diameter of 1/2" (12.7 mm).

05.0210 1 **DIMO 808 Diode laser module, 808 (+- 10) nm, 450 mW with Peltier cooler and XY adjustment holder**

The diode laser assembly consists of a precision XY adjustment unit in which the laser diode is mounted. The monitor diode for monitoring the laser output power, a Peltier's cooling element for the control of the diode temperature and a thermistor for the measurement of the temperature are all located inside the Laser Diode. A warning lamp, which signals the presence of laser radiation, is fitted to the upper side of the module. The diode laser module is connected to the control unit with the connecting lead.

07.0004 1 **Set of 4 BNC Connection leads**

BNC cable with a length of 0.8 m with attached BNC connectors on both sides

07.0102 1 **PIN Si Photo detector BPX 61 complete with housing**

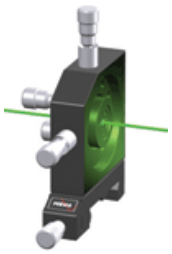
In a housing a PIN Si photo detector is mounted. Via a BNC connection the signal is fed to the respective pre-amplifier or oscilloscope. The module is clicked into the mounting plate, where it is fixed by means of three separate spring loaded balls which snap into the groove of the detector housing.

07.0200 1 **LDC01 Laserdiode controller**

The controller unit LDC01 provides reliable and save operation of the expensive laserdiode. It contains the control circuits for power monitoring, temperature control and current setting. The values for the temperature and the diode current can be read from two large-format LED displays on the front panel of the unit. The desired values for the temperature and current can be set with precision multi-turn potentiometers. At BNC sockets on the rear of the device, analogue output signals of the temperature and current as well as the synchronising signal of the internal modulator and the photodiode amplifier of the external photo detector are provided. Via a BNC socket, an external modulator can be connected. In addition the controller contains an internal modulator for modulating the laser diode output power for investigation of the dynamic behaviour of the pumped laser as spiking, measuring of lifetimes, etc.

09.0054 1 **Frequency doubling with KTP crystal**

A KTP - crystal with a size of 3 x 3 x 3 mm is used as a second harmonic generator. The crystal is mounted in a disk which is inserted into a „click" - holder which itself is clicked into an adjustment holder. This holder is adjustable in the X and Y direction and in two orthogonal angles. Furthermore the crystal can be rotated around its central axis to fulfil the phase-matching condition for optimum conversion efficiency.



10.0050	1	**EXP 05 manual**	**No illustration**

Required Options

19.0140 1 **Dual trace oscilloscope 100MHz**

Features:
Frequency Range: 150 kHz ~ 100MHz
Fully Digital Phase Locked Loop Technique Design
High Frequency Stability: ±10ppm
High Input Protection Level: +30dBm, ±25VDC
Reference Level Range: -30dBm ~ +20dBm

Options

07.0230 1 **FG-01 Linear triangle function generator**

This generator provides a linear triangle output with variable frequency in a range of 1 Hz to 20 kHz. Its main use is designed to provide a scanning signal for different controllers possessing an external modulator input.

09.0077 1 **Active Q-switch with a Pockel's - cell and HV driver**

The Pockel's cell is provided with an rotatable Brewster window. By loosening the screw with the supplied tools, the cap containing the window can be rotated. If a maximum output power is reached, the screw is fastened again. The Brewster window is covered by an additional cap which prevents the damage of the window as well as shielding laser stray light coming from the window. The Pockel's cell is connected to its driver with a special high voltage cable which forms an integral part of the assembly and should not be exchanged.