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DATA SHEET 711

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THE THERMOELECTRIC COOLER AND D.C. PROPORTIONAL TEMPERATURE CONTROLLER

INTRODUCTION

For all KDP type frequency doubling crystals, there are two methods of producing second harmonic generation (SHG). (a) Angular tuning requiring a doubly rotated crystal (45°Z, θ m) where θ m is the angle at which the second harmonic extra-ordinary ray and the fundamental ordinary ray satisfy the condition $n_{e2} = n_{o1}$. This is true for type I process. (b) Temperature tuning, requiring a singly rotated cut crystal (45° Z, 90° Y) where θm is 90° so that the input ordinary ray is plane polarized with its E vector perpendicular to the optical axis. This is a special case when the matching angle θ m = 90°. This is often called 90° phase matching or non-critical phase matching since the Poynting vector walk-off of the output extra-ordinary beam is non-existant.

Ninety degree phase match can be obtained in these crystals by varying the temperature of the crystal. The extra-ordinary index, is, in general, much more temperature dependent than the ordinary index. Thus by changing the temperature, it is possible to change the birefringence until phasematching is obtained for θ = 90°. Absence of walk-off enables the full length of non-linear crystal to be used. Thus, if possible, it is preferable to use this method over angle tuning in order to maximize the conversion efficiency.

Angle tuning in type I process for any given material cannot be used below a certain fundamental wavelength. Thus for ADP and KDP, angle tuning at room temperature is not practicable to produce SHG below 5240 Å and 5170 Å (fundamental) respectively.

Temperature tuning of a non-linear crystal is a powerful tool of extending the SHG below the wavelength 5240 Å by cooling the crystal below room temperature. The lower limit of temperature is set by the Curie temperature as well as the UV transmission of the non-linear crystalline material.

For producing SHG between the region of 5000 Å – 5240 Å, ADP material is more suitable because of better UV transmission and a steeper slope of λ vs temperature as compared to KDP. For doubling Argon-Ion laser radiation of 4965 Å and 5145 Å, ADP crystal should be cooled to –93° C and –10° C respectively. Similarly, the non-linear crystal ADA should be cooled to –40° C and 0° C to produce SHG from 5600 Å and 5780 Å (fundamental) respectively from a tunable dye laser radiation. However, this method requires slow tuning as the crystal should be heated or cooled at a rate less than 5° C per minute. The Curie temperature for ADP and ADA are –126° C and –57° C respectively. Both ADP and ADA are antiferroelectrics and will physically shatter if cooled below their Curie temperatures. Other KDP isomorphs lose their non-linear property below Curie temperature. This property reappears when the crystal is raised in temperature above its Curie temperature. The lower limit of optical bandwidth is 2600 Å for crystals of arsenates and 2400 Å for crystals of phosphate materials.

Efficiency of conversion from a cw laser source depends upon several factors: (1) the absorption of the crystal material at the fundamental as well as the SH frequency (2) the intensity of the focussed cw laser radiation within the crystalline medium (3) the length of the crystal (4) beam divergence (5) angular acceptance of the crystal (6) non-linear susceptibility coefficient (7) mode structure and other factors. In general, efficiencies are less than one-tenth of 1%. Typically from a TEM_{oo} mode Argon-Ion laser radiating 1 watt at 514 nm, output of about 400 microwatts are obtainable with a suitable focussing lens. The crystal is placed approximately half-way between the lens (38 cm F.L.) and its focus. The system is specifically useful for extracavity SHG experiments. Higher efficiencies are obtainable with intracavity doubling.

The cw or average power of the laser should not exceed 4–5 watts for this cooled frequency doubling system. If more power is pumped into the crystal, it will be heated beyond the capacity of the cooler to withdraw the heat.

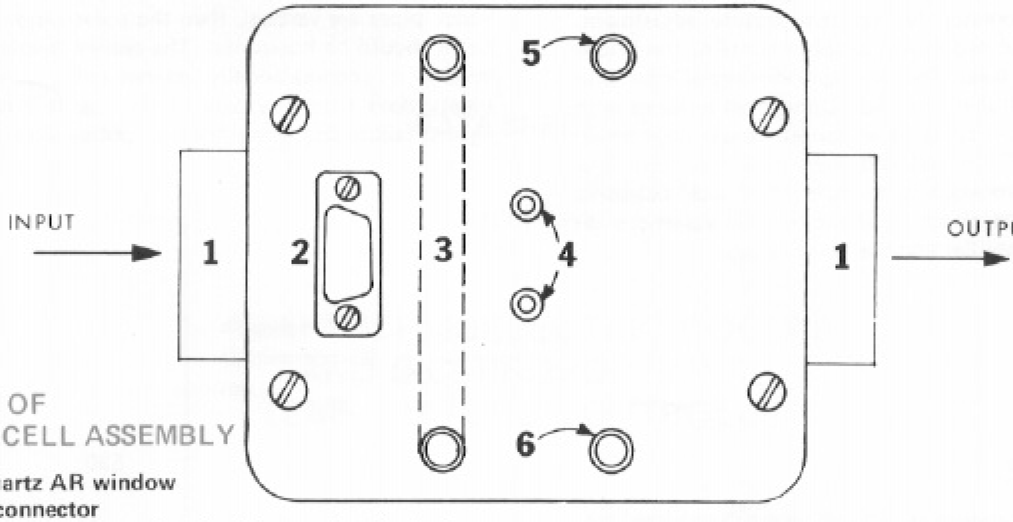
THE COOLED HOUSING:

The crystal housing is similar to our model AT-2 angle-tuned housing of outside diameter of 40 mm. The crystal is mounted on a heat sink and this is placed inside the housing. A crystal of KDP up to 50 mm can be accommodated in the housing. AR coated windows at the appropriate wavelengths, are used at the input and output ends to seal the crystal. The inside space around the crystal is filled with index matching inert fluid.

In order to avoid condensation of atmospheric moisture, two more fused quartz windows are utilized outside the anodized aluminum enclosure coaxially with the two fused quartz windows inside the enclosure. Thus there are two front windows with an airgap and two back windows also with an airgap. For most efficient operation, both the faces of the front windows are AR coated for the fundamental laser radiation. Both the faces of the back windows are also AR coated for the SH radiation.

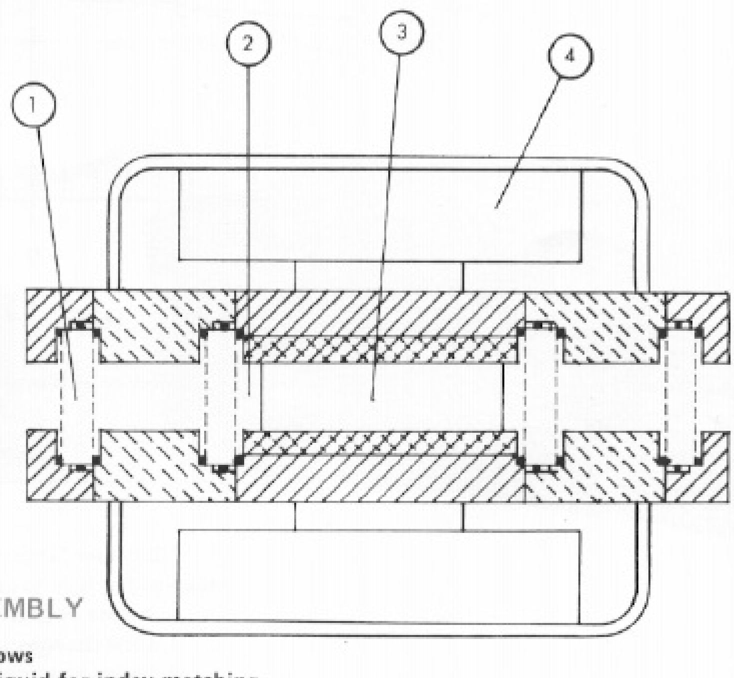
This housing is then sandwiched between two thermo-electric cooling modules of total capacity of 45 watts. The cold junctions are in close thermal contact with the housing for efficient cooling. The hot junctions have built-in water-cooled jackets. This composite assembly is placed inside an aluminum enclosure of about 10 x 7.5 x 12 cm^3. It is essential that the hot junction be kept at a constant temperature by passing tap water through the water jacket. On connecting the cooler to a proper D.C. source, a maximum temperature differential of 35° C is obtained between the cold junction and the hot junction. If the tap water at +15° C is passed through the water jacket, the hot junction will be kept at +15° C and the minimum temperature of the cold junction will reach –20° C. If ethylene glycol cooled down to 0° C is passed through the water jacket, the minimum temperature of the cold junction will reach –35° C. For harmonic generation of Argon-Ion laser radiation at 514 nm, a crystal rod of KDP, oriented at 45° Z for temperature tuning requires a temperature of about −13° C. It is a fortunate coincidence that crystal ADP requires a temperature, for phase matching of 514 nm radiation, very close to that of KDP crystal. However crystal KDP is a better choice at this wavelength because it is about one-half as temperature sensitive and its absorption per cm is also lower than that of ADP crystal.

The thermo-electric modules are electrically connected in series and one terminal (+ve) is connected to pin 1 and the other (−ve) is connected to pin 5 of the Cannon connector. A sensing thermistor (Yellow Springs Instrument part no. 44004) in thermal contact with the housing, is connected to pins 7 and 8. An indicating thermistor, identical in every respect, is connected to two separate black pins. An ohmmeter connected to these pins will indicate the resistance of the thermistor at any given instant and the temperature is read from a resistance vs temperature chart.



TOP VIEW OF
COOLING CELL ASSEMBLY

1 – Fused quartz AR window
2 – Cannon connector
3 – Plastic tubing connected to the Thermoelectric device
4 – Pin plugs for extra thermistor for monitoring temperature
5 – TED pipe to be connected to tap water
6 – TED pipe to be connected to drain



INSIDE VIEW OF
COOLING CELL ASSEMBLY

1 – Fused quartz AR windows
2 – Fluorocarbon FC 104 liquid for index matching
3 – Crystal 45° Z cut
4 – TED module for cooling the cell

THE D.C. PROPORTIONAL TEMPERATURE CONTROLLER:

Cooling of the housing containing the non-linear crystal is achieved by applying D.C. (6 volts at 7.5 amps) power to the thermoelectric module. Proper mating connector from this controller is connected to the Cannon connector on the cooling cell.

The D.C. controller is a precision solid-state device to ensure high reliability. A thermistor sensor is used in a constant resistance Wheatstone bridge network with a precision potentiometer to set temperature adjustment. An internally regulated power supply maintains the bridge voltage at a fixed level. The sensing bridge signal is fed into a high gain operational amplifier. Connected in series with the thermoelectric module, is an output power stage which receives an amplifier signal and controls the current flow through the thermoelectric module. Feedback networks compensate for the effect of environmental variations on the operational amplifier and the power stage.

Specifications:

1. **Direct Dialing:**

   With the temperature vs dial setting graph provided any control temperature between −30° C to +15° C may be directly selected with an accuracy of ±0.5° C.

2. **Temperature Stability:**

   Short term: ±0.01° C
   Long term: ±0.05° C

3. **Control Range:**

   +15° C to −30° C

4. **Power Input:**

   117 Volts, 50 Hz or
   60 Hz, 225 watts
   (220 volts on special request)

5. **Controller Output:**

   6 Volts at 7.5 amps

6. **Size:**

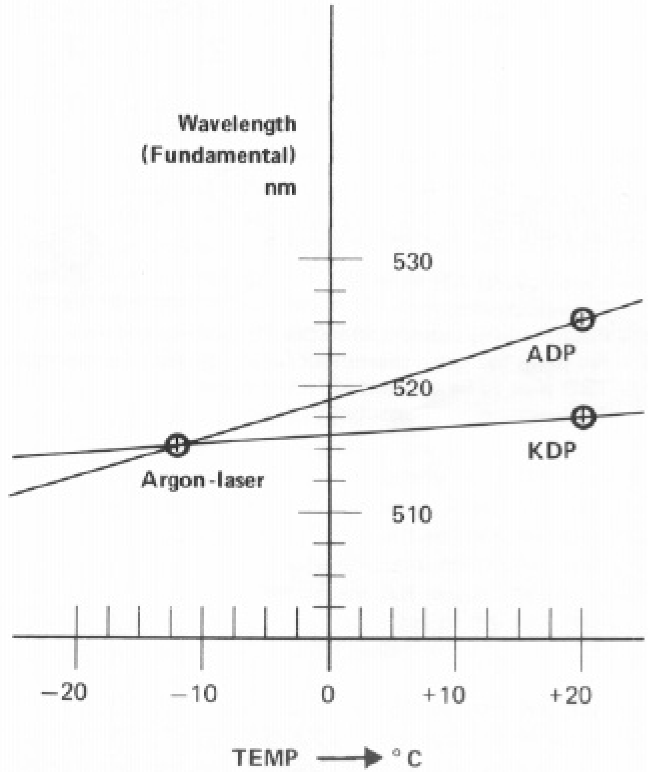
   20 x 20 x 30 cm^3

7. **Weight:**

   15 kg

Operation:

The tuning curve in the temperature range of the cooler from −30° C to +15° C is given on a graph for ADP and KDP crystals. The temperature required will depend upon the wavelength of the laser and the type of the crystal used in the cooler. The crystal is placed in the cooler, so that its optic axis is parallel to the water pipes of the thermoelectric module. Therefore if the cooler is placed so that the water pipes are vertical, then the polarization of the input beam should be horizontal. The cooled frequency doubling system is unconditionally guaranteed against failure for ninety days from the date of invoice. It is not warranted against failure due to electrical or optical abuse.



Fundamental Wavelength vs Temp
