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Report Number BEI-75 - 656

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RDA RUBY LASER FREQUENCY DOUBLER SYSTEM

Final Comprehensive Report

by

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February 1976

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This report describes the modification and updating of the Remote Raman system at Edgewood Arsenal. Several technical and engineering innovations were incorporated into the remote Raman system. These included: 1. Replacement of the existing KD*P (potassium dideuterium phosphate) doubling crystal with a more efficient RDA (rubidium dihydrogen arsenate) system. 2. Installation of a motorized drive on the polychromator positioning rails to facilitate alignment in the X and Y directions. 3. Addition of new mirror mounts

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in the ruby laser to increase long-term optical stability, and 4. The correction of various minor optical and mechanical problems. The modifications have resulted in an overall improvement in performance, stability, and ease of operation of the remote Raman Spectrometer.

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PREFACE

The work described in this report was authorized under Project/Task 1W762710AD27-02, Remote Sensing Alarm Technology. This work was started in April 1973 and completed in April 1974.

Acknowledgements

We wish to thank Mssrs. Harvey Tannenbaum, David Tanenbaum, and Harry De Long for their invaluable guidance on this program.

INTRODUCTION

1. General

1.1 Program Scope

This is the Final Technical Report for Contract No. DAAA15-73-C-0183 entitled, "RDA Ruby Laser Frequency Doubler System". The intent of the work performed under the scope of this program was to upgrade the performance of the remote Raman instrument delivered to Edgewood Arsenal, Maryland under Contract No. DAAA15-70-C-0418.

In order to meet the program objectives, several technical and engineering innovations were incorporated into the remote Raman system. These included:

(1) Installation of a rubidium dihydrogen arsenate (RDA) second harmonic generator system to obtain a higher conversion efficiency of the visible ruby laser output to the desired ultraviolet radiatior.

(2) Addition of a motorized drive on the polychromator positioning rails to permit easier and more accurate location of this unit in both the X and Y directions.

(3) Incorporation of new mirror mounts in the ruby laser to facilitate optical alignment and to improve its long term stability.

(4) Correction of various minor optical and mechanical problems to improve system stability.

1.2 Program Results

The modifications made to the remote Raman system have resulted, for the most part, in improved performance and instrument stability. In some cases, however, the improved performance may be offset by the complexity that is added to the Raman unit. Table I summarizes the effect each of the four (4) tasks had on the system. These are discussed in more detail in Sections 2 to 4 of this report.

Table 1. Summary of Effects of Modifications to Remote Raman Spectrometer System

Task	Performance	Stability	Ease of Operation
RDA Second Harmonic Generator	+	-	-
Polychromator Drive	0	0	+
Mirror Mounts	0	+	+
Miscellaneous Mechanical and Electrical Changes	0	+	+

Code: + = Improved
0 = Unchanged
- = Worsened

RDA SECOND HARMONIC GENERATOR SYSTEM

2. General

2.1 Objective

The objective in developing a RDA (rubidium dihydrogen arsenate) second harmonic generator system was to improve the performance and reliability of this subassembly in the extant remote Raman system. In particular, these goals were to by met by:

(1) Improving laser output power in the ultraviolet region (0.347 μ) by replacing the existing KD*P (potassium dideuterium phosphate) doubling crystal with a more efficient RDA system.

(2) Increasing the repeatability of the doubling efficiency (on a pulse to pulse basis) by more accurate alignment and precise temperature control of the RDA crystal.

(3) Extending the life of the RDA doubling crystal by proper environmental control.

2.2 Performance Goal

The goal of the present work was to obtain a laser output power of 400 to 500 mJ per pulse at 0.347 μ. The input power source was to be a 2 J ruby laser operating at a repetition rate of 2 pulses per second. This meant that an RDA doubling efficiency of 20 to 25% was required. In addition, it was desired that the output power not vary more than ±5% from pulse to pulse.

2.3 Background

The ultimate goal, when developing a remote Raman C-agent detector is to see the smallest agent concentration at the greatest range in the shortest observation time with the lowest number of false alarms and with zero misses. Each of these criteria is dependent on the others, and possible tradeoff situations exist. For example, lower concentrations can be seen if the analysis time is increased and all other parameters remain constant. Therefore, if sensitivity is increased, this can be traded, if desired, for improvements in the other operational requirements.

There are many ways, of course, to increase sensitivity. For this program, however, one of the criteria was that no major redesign of the existing remote Raman spectrometer was possible. This limited the number of options to:

(a) increased collector size,

(b) decreased range,

(c) increased integration time,

(d) improved detector quantum efficiency, and

(e) increased laser power output.

2.3.1 Reasons for Rejecting Several Approaches to Increased Sensitivity

When selecting an approach to improved system performance, it is necessary to weigh the gains against the effort expended. This was done as part of this program to ensure that the recommended approach was most effective. The conclusions were:

(1) If the collector size were increased beyond its present 91-cm aperture, the signal-to-noise ratio would only improve linearly with radius. Furthermore, these optics are already too large to be practical and any further increase in size would result in an unwieldy system. There is also a question as to whether this would be economically justifiable.

(2) Decreased range is contrary to the presently desired operational scenario and ultimate deployment scheme. Ranges must be increased, not decreased.

(3) Increased integration time is not permissible as the allowable integration time is not arbitrary but defined by the length of time the sample cloud will fill the field-of-view of the spectrometer. This is nominally in in the 10-second range. For experimental purposes, increased integration time is available on the present instrument and needs no modifications. The integration times needed and the present spectral scan techniques use up large amounts of laser life and a further increase is not desirable.

(4) Improved detection system quantum efficiency, through the use of better photomultiplier tubes, is possible but at best would only double or perhaps triple present signal level without reducing noise level at all. In fact, for higher quantum efficiencies the noise level increases as much as the signal level in such a background limited situation.

(5) Increased laser power output by replacing the laser with an upgraded unit could not be considered as an approach which was in keeping with the limitations of the program because it required a major redesign and was very costly.

2.3.2 Rationale for Selecting Improved Second Harmonic Generators

The most direct method of increasing system performance without changing the operational parameters is to increase the number of photons available to excite the sample. This is most easily accomplished by increasing the efficiency of the second harmonic generator (SHG) frequency doubler. The present system uses a KD*P SHG which gives a nominal 8% doubling efficiency. The selected RDA material was estimated to be about three (3) times more effective and expected to give 25% doubled frequency output efficiency. Thus with only the slightest system perturbation a factor of 3 should have been attained.

2.4 RDA Doubler Assembly

Several new crystal materials are now available which provide enhanced efficiency at doubling the frequency of ruby laser radiation. These materials (RDA, RDP, ADA, KDA) are primarily arsenic compounds and achieve phase matched operation near 90° orientation. In such a configuration, the deviation from match for a slightly off axis ray is much less than for 0 or 180° phase matched crystals. Hence off axis rays are doubled almost as well as rays which are perfectly collimated. The acceptance angle for RDA for example is 3 mrad vs. 0.1 mrad for KDP. From laboratory experiments it has been demonstrated that Z-cut RDA operating at 96.0 ±0.1° C is the most efficient second harmonic generator for ruby laser light (0.694 μm). A system which incorporated RDA was, therefore, designed, constructed and installed on the existing remote Raman unit.

2.4.1 Mechanical Configuration

The mechanical arrangement of the RDA system is shown in Figure 1. This drawing shows six (6) main subassemblies:

(a) RDA crystal,

(b) crystal holder,

(c) RDA cell,

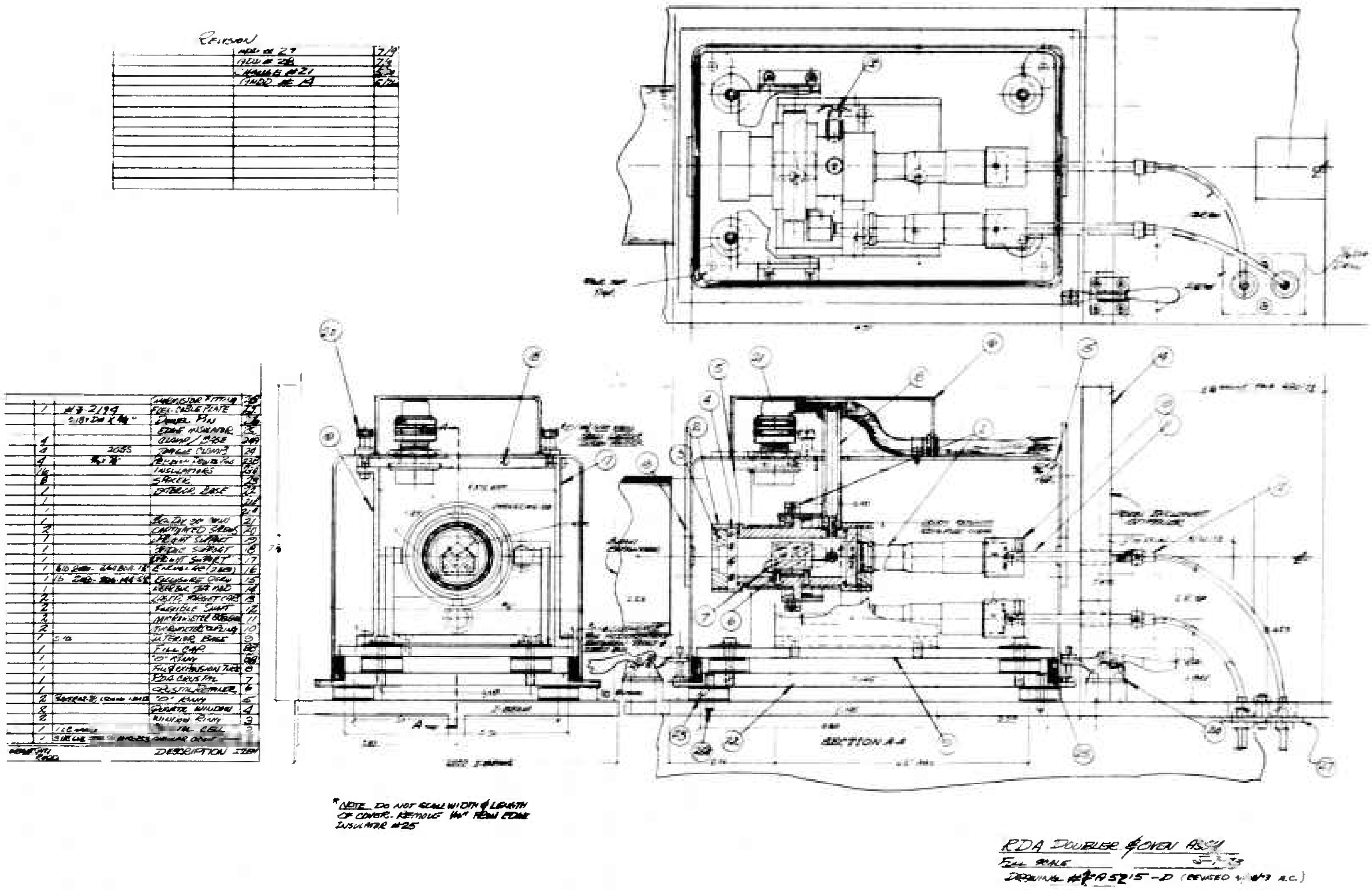


Figure 1. Mechanical Layout of RDA Subassembly

(d) cell holder,

(e) thermal package, and

(f) thermal controller.

2.4.2 RDA Crystal

For maximum doubling efficiency, the RDA crystal is cut (Z-cut) so that when it operates at 96° C, it is angle matched (90°) to the ruby laser pump. In addition, the input and output faces of the crystal are polished. Damage threshold for the crystal was specified to be greater than 100 Mw cm^{-2}. A typical crystal is shown in Figure 2.

2.4.3 Crystal Holder

The purpose of the crystal holder is to rigidly mount the RDA crystal so that it can be properly aligned. This holder is also a subsystem in the assembly used to maintain long-term optical alignment.

The crystal holder is shown in Figure 3. It consists of an aluminum trough with a groove into which the crystal fits. A beryllium-copper spring finger holds the crystal in place (Figure 4). Recessed Teflon end plates (Figure 5) are used to secure the crystal faces.

2.4.4 RDA Cell

The RDA cell is used to provide the proper environment for the RDA crystal. It is a cylinder into which the crystal holder fits (Figure 6). It has windows at each end through which the primary ruby laser light enters (0.694 μm) and the frequency doubled ultraviolet radiation (0.347 μm) exits. The entrance

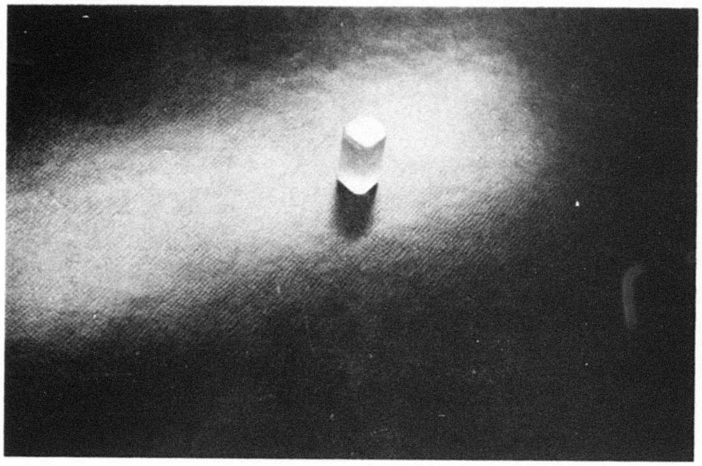


Figure 2. RDA crystal

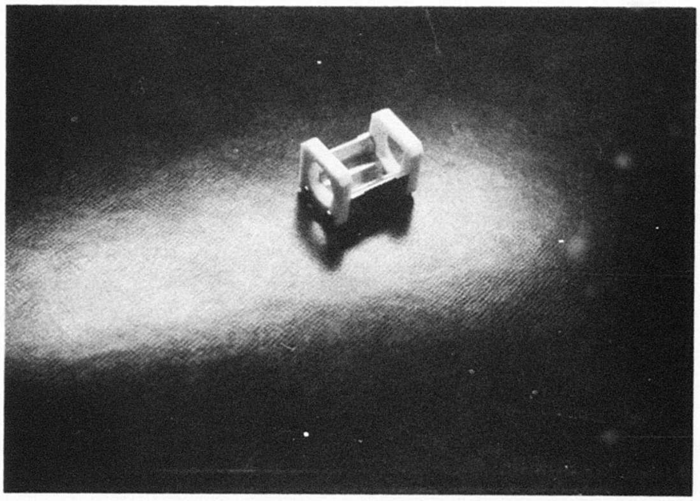


Figure 3. RDA crystal holder

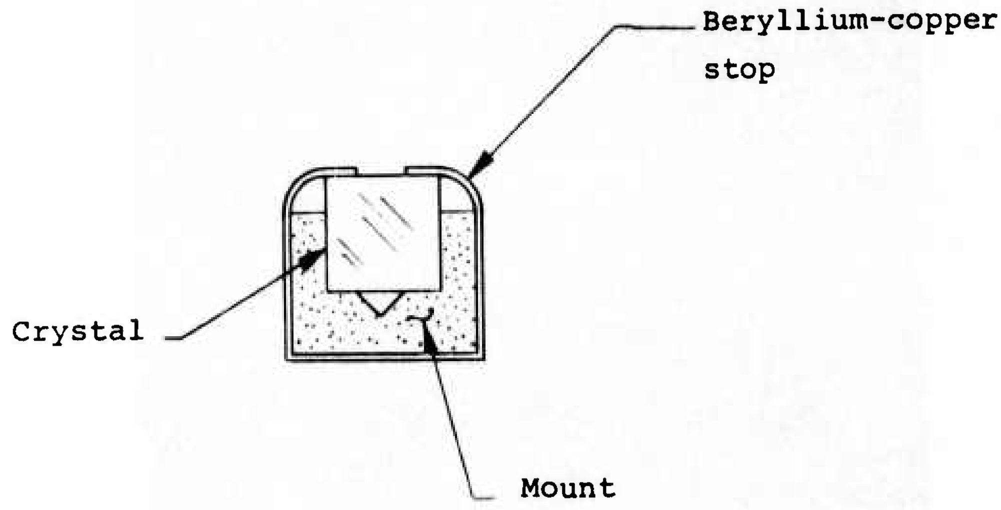


Figure 4. Crystal mount

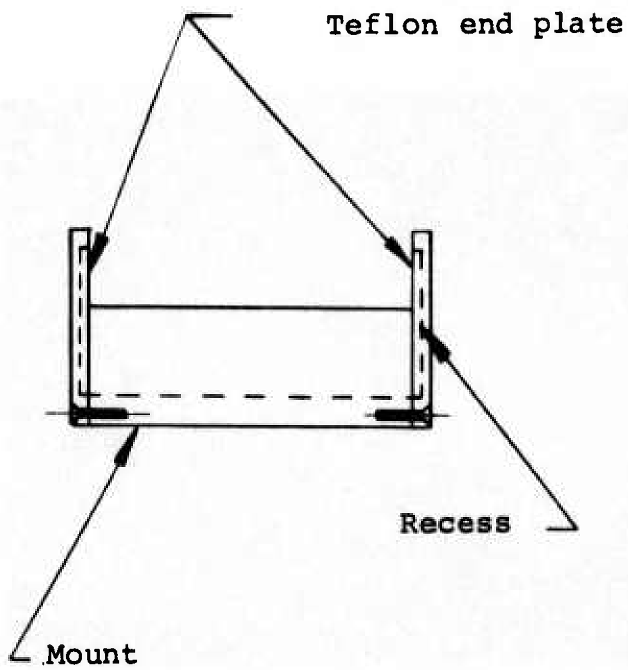


Figure 5. Crystal mount with Teflon end plates

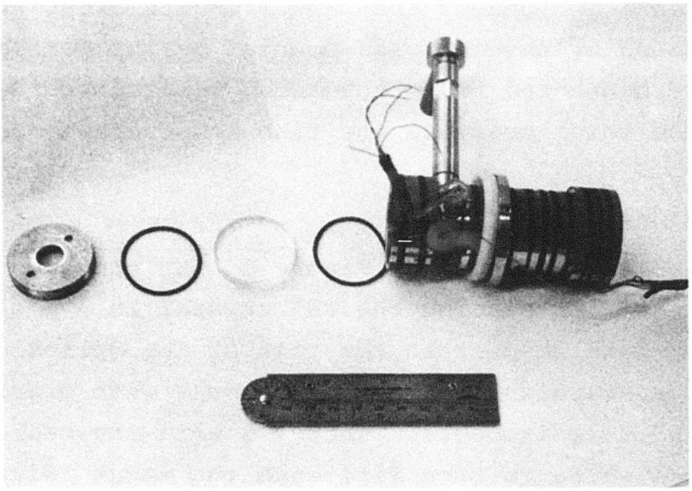


Figure 6. RDA cell components

window is AR coated to pass the 0.694 μ light, and the exit window is AR coated to reject the 0.694 μ radiation while passing the 0.347 μm ultraviolet energy. The cell is filled with an index matching liquid (such as FC-43 fluorocarbon) to provide a uniform temperature bath for the crystal. The cell is filled through a stand-pipe which also acts as a pressure relief valve and provides a reservoir for expansion of the fluid during heating. All cell components are made from stainless steel. The cell is heated by thermal pads mounted on its periphery. The heaters are connected to an automatic temperature sensing and servo device which provides the fine temperature control.

2.4.5 Cell Holder

The cell holder is shown in Figure 7. It provides a stable accurate mechanism for placing the RDA crystal in a position that is optimum with respect to the rest of the optical system. It consists of a stainless steel Ealing mount with micrometer-controlled X and Y positioners. The cell with its heaters is placed in a yoke which in turn fits into the mount (Figure 8). All alignment adjustments are made from outside the RDA assembly by use of flexible cables.

2.4.6 Thermal Package

A thermal package was designed into which the cell holder fits. It consists of a thermally isolated base plate onto which the cell holder is mounted and an aluminum can to enclose the whole system. The base plate is tapped and kinematically mounted so that it fits on the "I-beam" rail of the laser in place of the present KD*P doubler assembly. The can has two holes so that the laser beam can enter and exit. The entire RDA assembly can be installed or removed from the extant Raman system without any major optical realignment because of the precision to which the base plate fits on the "I-beam" rail.

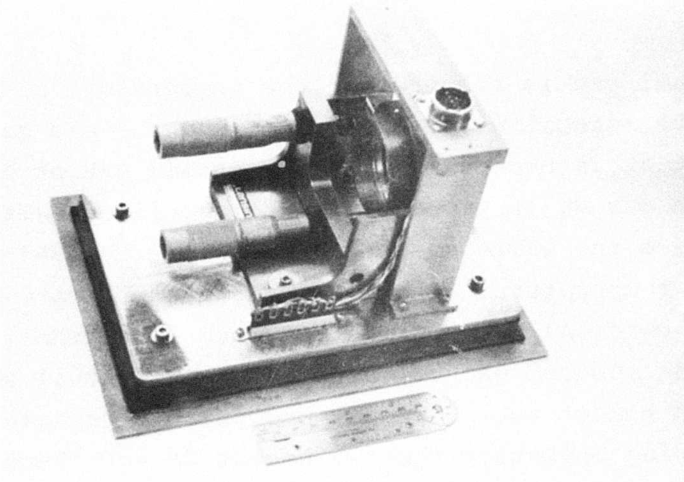


Figure 7. RDA cell holder

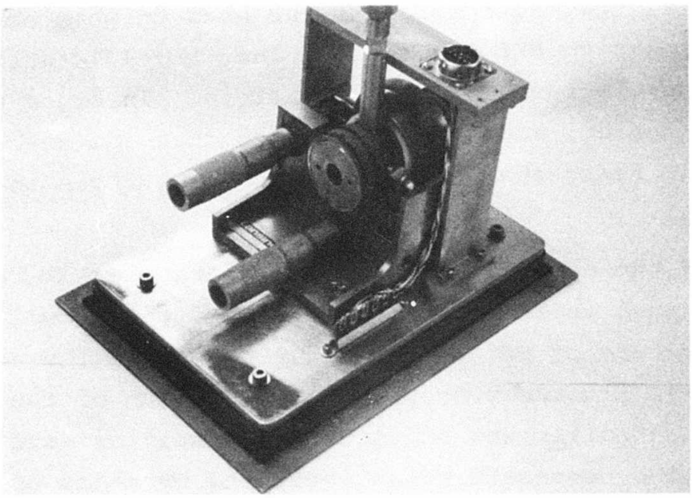


Figure 8. RDA cell in its cell mount

The external can is required if the temperature of the crystal is to be maintained at 96 ±0.1° C under field conditions. In fact it is necessary to use a second set of heaters attached to the can walls (in addition to the fine heaters on the cell) to keep the whole system in the vicinity (96° C ±3° C) of the desired temperature. The heaters can compensate quickly for changes in external temperature and thus leave the cell heaters for fine control only. There is an individual servo system for each heater set. Special provisions are made to assure that during operation the two servos do not "hunt" each other. The system also has a "fail-safe" mechanism to make sure that the cell does not overheat or change temperature too rapidly. Thermistors are placed at strategic points on the cell and thermal package to sense the system temperature.

2.4.7 Thermal Controller

A commercial thermal controller was used on this program (Figure 9). It was an RFL industries, Inc. Model 70 unit. This controller is manufactured with 5% resistors. In order to obtain much faster switching, and thus a more accurate and stable temperature control, 1% resistors were substituted for those in the original instrument.

As part of the effort to set up the controller it was then necessary to adjust it in order to keep the doubler cell at a constant temperature of 96° C ±0.1° C. To do this the cell was filled with FC-43 Fluorocarbon prior to insertion of the RDA crystal. The controller was adjusted for a heating rate of 5° C/min., and the temperature was monitored by means of a thermistor placed inside the cell and immersed in the FC-43 liquid. When the controller responded properly, even when the cell body was subjected to both fast temperature changes of several degrees

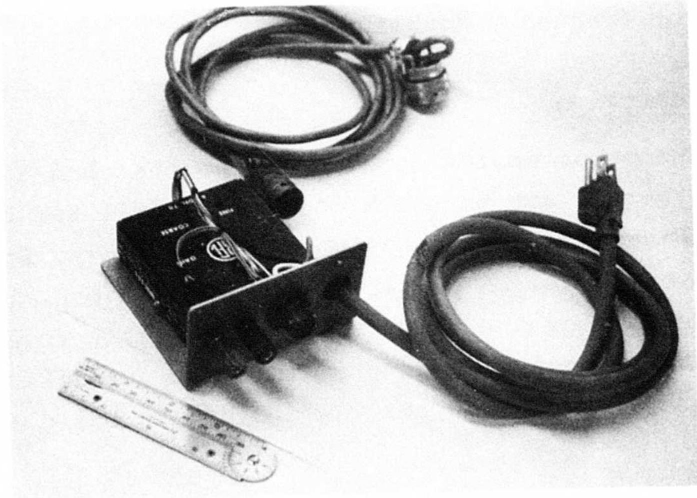


Figure 9. RDA thermal controller

centigrade and to cooled air blown over it, then the RDA crystal was inserted and the response checked again.

2.5 System Versatility

When developing a new system it is desirable to make it as versatile as possible. In particular, the second harmonic generator system that was delivered under this contract can be used with a variety of sizes and types of doubling crystals with minimum installation time and essentially no major optical alignment. This means such materials as KDP, KD*P, RDP and RDA can be used for frequency doubling.

2.5.1 Cell Selection

One of the major design considerations that had to be faced was whether or not to use a commercial cell for the RDA. The best unit available was from Quantum Technology, Ltd. which grows the RDA crystals. A comparison was, therefore, run between the Quantum Technology and Block Engineering cells to determine if the cost of completing the custom unit was justified. Based on the following conclusions, it was decided to build the new cell:

(1) The distance between the RDA crystal and the windows is much smaller in the Quantum Technology cell than in the present unit. For uniform thermal control (ample fluorocarbon thickness between the cell faces and windows) and the ability to use crystals of varying length, the greater distance between the crystal and the window is necessary.

(2) In the Quantum Technology unit, the crystal is held in place by a Teflon sleeve while the Block Engineering design uses a metal spring clip with a Teflon pad

and Teflon stops. Experience has shown that the Teflon becomes slippery when the fluorocarbon is added and the crystal can slide against the cell window and be damaged. The present design uses stops to prevent crystal motion. There is not enough room in the Quantum Technology unit to include the stops.

(3) The present system uses thermal pads to heat the cell while the Quantum Technology unit uses cartridge heaters. The Block Engineering design gives the extra heating capacity necessary for a field unit. In addition, more homogeneous heating results from the thermal pad blanket.

(4) The Block Engineering unit uses a vent tube for expansion of the fluorocarbon fluid while the Quantum Technology unit uses a small bellows diaphragm. The reliability of the bellows is questionable especially since Quantum Technology uses FC-77 fluorocarbon in their cell (vapor pressure = > 42 mm Hg at 96° C) which exerts a much higher vapor pressure than the FC-43 fluorocarbon (vapor pressure $\sim$ 0.3 mm Hg at 96° C). Bellows rupture can occur which could result in loss of the RDA crystal and system down time.

2.5.2 Cell Interchangeability

Even though the custom cell is considered to be superior to commercial units, it is conceivable that there may be a time when doubling crystal already mounted in cells will be used. To provide for such a contingency, the cell holder is designed to accept a variety of cylinder-shaped cells.

2.6 RDA Crystal Damage

One of the main problems that occurred, and was never solved, during this program was damage to the RDA crystals during operations which made them unuseable. This difficulty was first observed in the laboratory when the system was tested. Moderate input ruby laser power of 0.8 J with a pulse width of 25 ns was used. Temperature was controlled at 96° ±0.1° C. After 200 firings internal bubbles were observed which rendered the crystal inoperable. This occurred in both the laboratory and in the field.

There are several possible causes of crystal damage that can be hypothesized:

(1) Nonuniform energy (or "hot spots") in the laser beam could cause localized heating. This cause was rejected because the burn pattern of both the laboratory and Edgewood ruby lasers was very uniform.

(2) The effects of many laser firings could cause cumulative damage. This did not appear reasonable as damage was always observed after only a few hundred laser pulses.

(3) A high repetition rate of laser firing could cause overheating. This was considered unlikely for a low power laser which pulses only every thirty (30) seconds.

(4) Pressure build-up in the cell due to expansion of the fluorocarbon liquid could cause deformation of the crystal lattice. This was found to be a problem and corrected by putting a vent hole in the cap of the filter spout. It did not, however, correct the crystal damage problem.

(5) The crystal did not have a damage threshold of 100 Mw cm^{-2}. If so, then damage would occur regularly. This was deemed to be the most likely cause of the damage problem but could not be confirmed.

2.7 Frequency Doubling Efficiency

The doubling efficiency of the RDA system was measured at 20% in the laboratory where ruby laser output is accurately known. On the field system, where ruby laser output is varied, only 8% conversion was observed for a 0.5 J pulse while a 20^{+}% efficiency was estimated for a 1.5 J pulse.

The main problem with obtaining maximum conversion efficiencies is the very restricted temperature range in which the RDA crystal performs well. This was evaluated in the laboratory and the doubling efficiency was determined as a function of crystal temperature. Figure 10 shows just how narrow a temperature range is allowable for a large conversion capability. Here a change of 1° C from the center temperature results in only 4% doubling efficiency rather than 20%.

A second area of concern is the fact that the maximum efficiency center temperature was determined to depend on the angle of the light path to the crystal face. Angular deviation of a few degrees from the normal can shift the optimal operating temperature by 3 - 5° C, while maintaining the very narrow temperature range around the optimal temperature unchanged. This means that unless the alignment is accurately maintained the thermal controller may keep the crystal at a temperature where it gives little or no doubling efficiency.

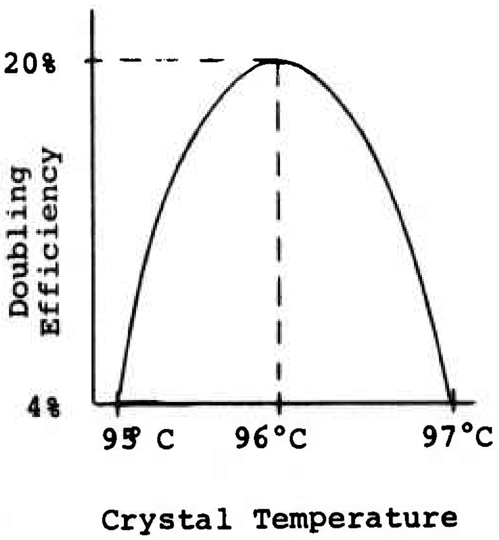


Figure 10. RDA crystal efficiency-temperature relationship

POLYCHROMATOR DRIVE

3. General

3.1 Objective

Positioning of the polychromator on the remote Raman system (before this modification) was done by manually moving this unit along metal slides. To make focusing the polychromator easier and to facilitate positioning the image within the slit, a modification was undertaken to provide for the positioning of this subassembly by means of two (2) independent motorized drives.

3.2 Polychromator Drive Assembly

The polychromator drive consists of two separate systems:

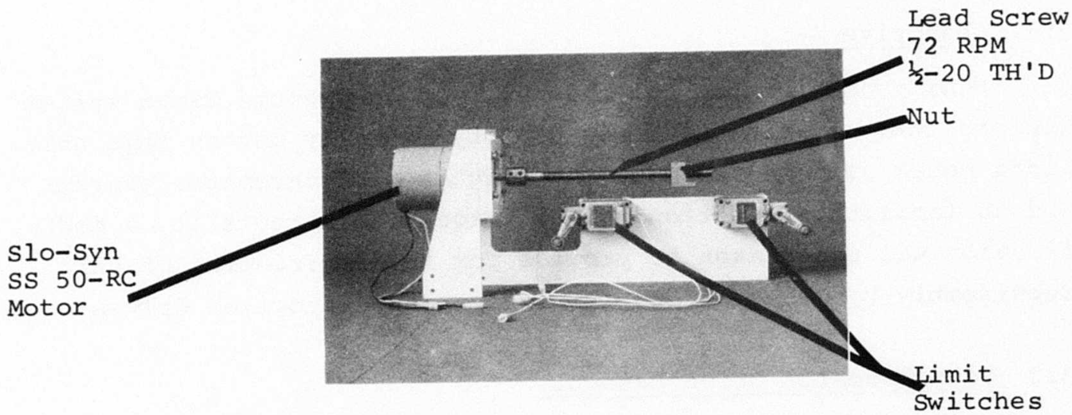
(1) A focus adjustment which moves the polychromator further or closer to the telescope.

(2) A positioning device that moves the polychromator side to side in a direction perpendicular to the output of the optical collector.

3.2.1 Focus Adjustment

The focus adjust unit is illustrated in Figure 11 (fore and aft position). It must have a positional accuracy of 0.5 inch or better. This accuracy is a function of the speed with which the control switches can be operated and the overall system inertia. The drive motor chosen is a Superior Electric Co. "Slo-Syn" Model No. SS50-RC. This motor has an output speed of 72 rpm and an output torque of 50 oz. inches. This motor drives a 1/2-20 lead screw which provides a movement of 3.6 inches per minute, or 0.06 inches per second.

Front View



Rear View

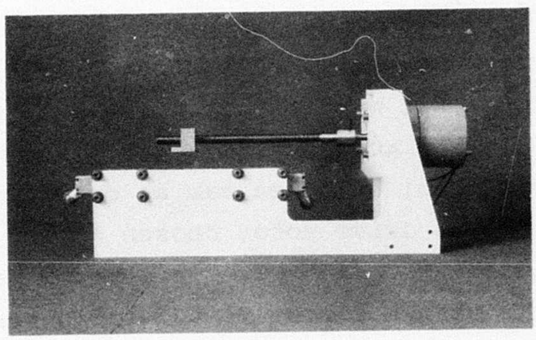


Figure 11. Polychromator focus control mechanism

When a momentary on action switch is used, the maximum system response time from full speed to no motion was determined to be 2 seconds. This gives a total over-run travel of 0.12 inch (0.06 in s^{-1} x 2 s), which is approximately 4 times better than the required accuracy of 0.5 inch. The output torque of the chosen motor was felt to be more than adequate, even when the system is in the elevated position, as the polychromator is mounted on ball slides in the fore and aft mode. Any frictional forces, therefore, are negligibly low, and any inertial forces are overcome by the combination of available motor torque and the torque multiplication of the rotary to linear conversion in the lead screw-follower arrangement. Maximum travel is limited in both directions by over-travel limit switches which interrupt power to the drive motor.

3.2.2 Side to Side Adjustment

The side-to-side adjustment illustrated in Figure 12 must have a positional accuracy of 0.005 inch or better. The motor chosen for this application is a "Slo-Syn" Model No. SS50-P2-RC. This motor has an output speed of 3.3 rpm and an output torque of 600 oz. inches. The output speed is further reduced (and the torque amplified) by the employment of a 3.3 to 1 reduction ratio sprocket and chain drive which also splits the output into two shafts. The speed of these two shafts will be 1 rpm and each shaft drives a 1/2-20 lead screw. This provides for a travel of 0.050 inch per minute, or 0.000833 inch per second. With system response time similar to the focus drive (2 seconds), there will be a maximum over-travel of 0.00167 inch (2 s x 0.00083 in s^{-1}). This is approximately 3 times better than the required 0.005 inch.

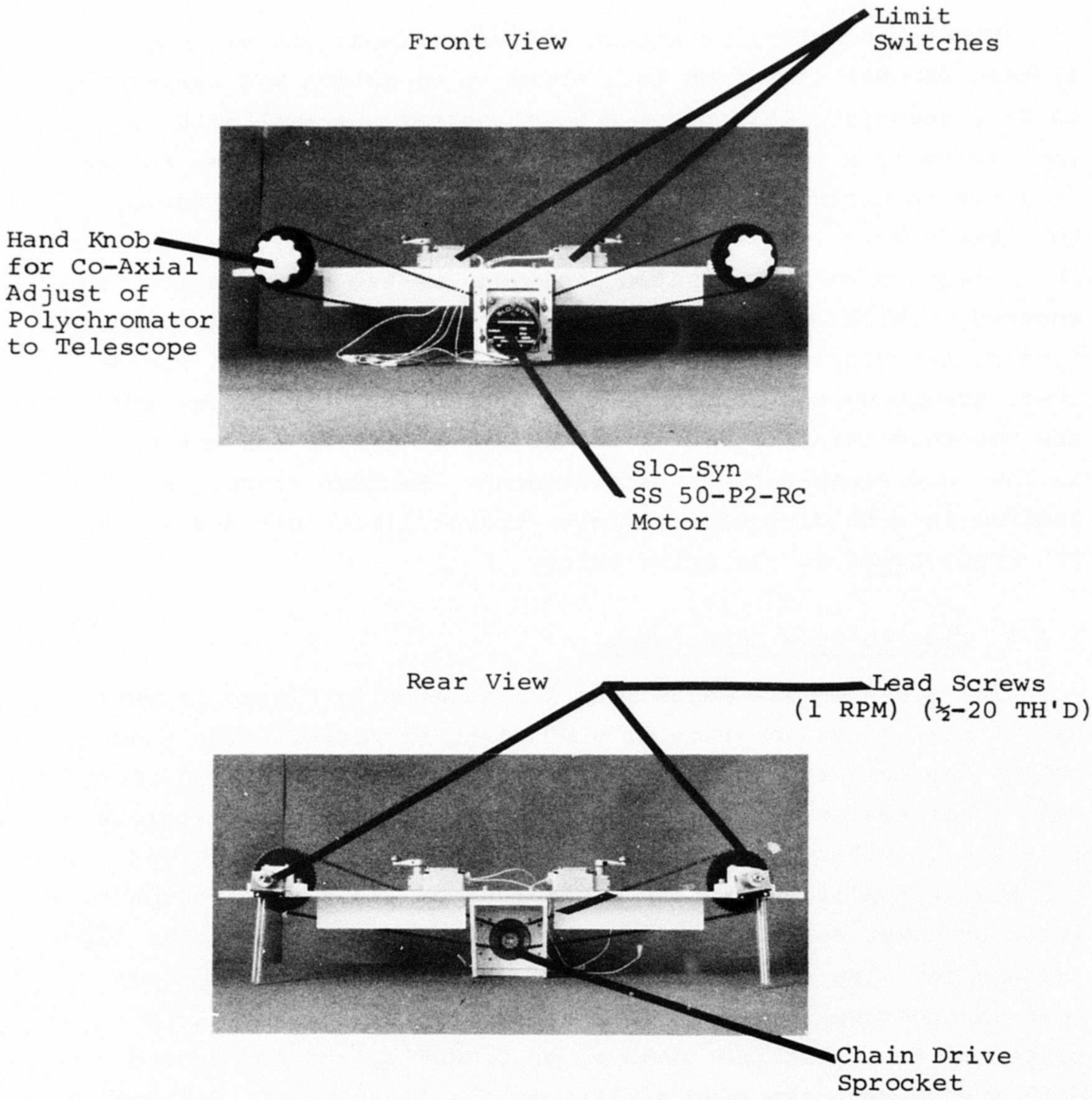


Figure 12. Polychromator side-to-side adjust mechanism

In this side-to-side mode the frictional forces are much more significant than in the focus mode. For this movement, the structure of the polychromator slides metal to metal against its bottom support. This requires a significantly larger amount of torque (approximately 40 times greater) than does the focus adjust. The estimated amount of torque required to move the polychromator in the side-to-side mode through both screws collectively is 5 foot pounds. The torque available is as follows:

Motor output = 600 in. oz. x 3.3 (chain drive)
Shaft output = 1980 in. oz.
Required torque = 5 ft. lb. = 960 in. oz.

This indicates that there should be a substantial safety factor available, even though a 100% efficiency is assumed in the sprocket-chain drive. There are two reasons for driving the side-to-side adjust with two shafts:

(1) To attempt to move the relatively massive polychromator with such high frictional forces from a single point without some type of guide would not be practical or effective.

(2) Coaxial alignment of the polychromator with the telescope can be achieved by loosening 6 screws which are clearly marked in red. This disconnects the chain and motor drive, and alignment is obtained by manually turning the two hand knobs individually to the desired position. Upon retightening the six screws, the motorized side-to-side adjustment can then resume from either of the control boxes provided.

3.2.3 Drive Controls

The control boxes are pictured in Figure 13. One control box is mounted on the front of the polychromator, where it is available to the operator while he is looking into the eyepiece located on the top of the unit. The "remote" box (Figure 14) is located at the rear of the trailer next to the electronics and status panels, so that polychromator adjustment can be accomplished while viewing the system output.

The two control boxes are coupled in such a fashion that alternating operation is possible, that is, a function may be enabled from one station and disabled from the other.

Twenty feet of cabling are supplied to electrically couple both boxes, and a 110 volt ac receptacle is also provided for a standard line cord at the rear of the remote box. All other power is distributed through the supplied cable assemblies.

3.2.4 Drive Installation

The polychromator drive system was installed on the remote Raman system without any problems. Figure 15 shows the side-to-side adjust mechanism in place. The only apparent drawback of this system is the time it takes to make an adjustment. As previously noted, the rate of movement is directly related to the positioning accuracy required and thus the slowness of the drives cannot be improved without sacrificing more important specifications. With this one exception, the drive unit has greatly improved ease of Raman system operation.

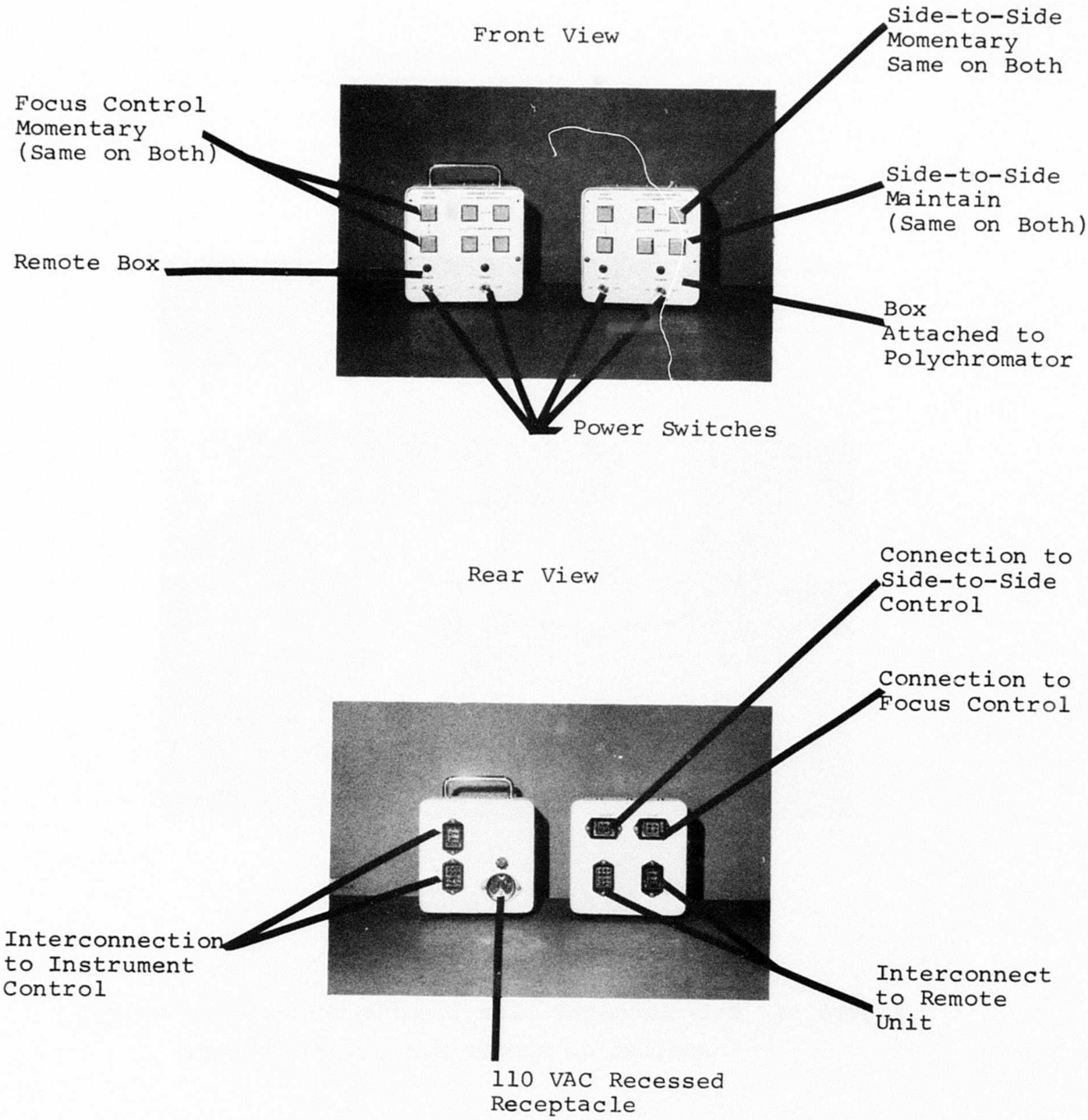


Figure 13. Polychromator control boxes

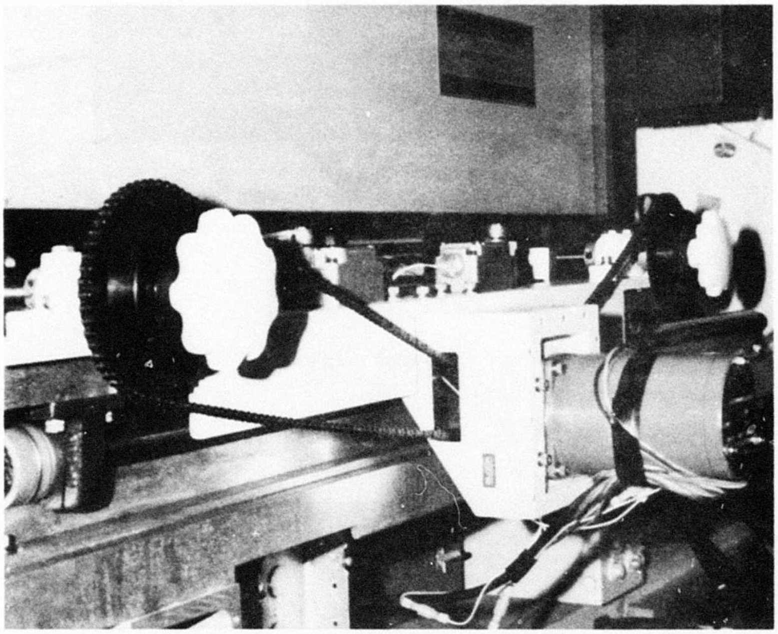


Figure 14. Polychromator side-to-side positioning drive installed on Remote Raman spectrometer

MISCELLANEOUS MODIFICATIONS TO THE REMOTE RAMAN SYSTEM

4. General

4.1 New Laser Mirror Mounts

The mirror mounts that were supplied by Space Rays, the manufacturer of the Ruby laser used in the remote Raman system, were found to be unstable and difficult to adjust. These were, therefore, replaced by Lansing mirror mounts. The new mirror holders are controlled by micrometer screws and this allows more accurate positioning of the mirrors in both the horizontal and vertical positions. The Lansing mounts also hold their settings much more accurately than the original units over long time periods and this results in increased alignment stability for this part of the optical system.

4.2 Cooler Modifications

Gauges were installed on both the high and low pressure sides of the compressor for the laser cooler. The laser cooler has been a major contributor to system "down-time" and it was decided to monitor the compressor function in an effort to foresee any developing problems. The connections were later found to be major sources of leaks and these problems caused the greatest problems.

4.3 Periscope for the Polychromator

In order to maximize the return signal of the remote Raman system, it is necessary to ensure that the polychromator system is in focus. This is done visually by inserting a periscope into the polychromator which permits observation of the image of the target as it appears at the entrance slit. During this program a telescope was installed on the polychromator.

CONCLUSIONS AND RECOMMENDATIONS

5. General

5.1 Conclusions

The work performed during this program has resulted in a more utile remote Raman spectrometer. The degree of success varied as discussed in the following subsections.

5.1.1 RDA Second Harmonic Generator

Doubling efficiencies of approximately 20% have been observed using RDA second harmonic generators. In essence this would mean that the goal of this part of the program had been met. In fact, however, the problem with crystal damage makes implementation of the RDA system impractical.

The crystal damage problem was evaluated in detail. Use of several lasers with uniform burn patterns indicated that "hot spots" could be a cause of damage. Use of lower laser repetition rates showed that too frequent laser pulses did not affect crystal lifetime. Finally, putting the RDA crystal into several crystal cell configurations and operating with and without index matching fluid eliminated the contribution of pressure and other cell anomalies to crystal deterioration. In addition, the resultant data points to the fact that the damage threshold of the RDA crystals is much lower than the 100 Mw cm^{-2} specified by the manufacturer. There is no immediate solution to this last problem.

The conclusion that must be drawn is that the RDA doubler system is potentially a good method of frequency doubling a red ruby laser into the ultraviolet region but the system cannot be practically implemented until RDA (or the equivalent) crystals with reasonable damage thresholds are grown.

5.1.2 Polychromator Drive

The polychromator drive accomplished what was required. The remote Raman spectrometer system set-up and alignment has been greatly facilitated by this device.

5.1.3 Mirror Mounts

The mirror mounts have greatly improved Raman system operation. Optical alignment of the laser has been greatly simplified and the long term optical stability has made day-to-day operation much more straightforward. In addition, because the laser stays aligned over longer operational times, laser power remains maximized and this indirectly contributes to enhancing long term system performance.

5.2 Recommendations

The present remote Raman spectrometer is a five-year-old, first-of-a-kind breadboard. During this period of time a great deal has been learned about remote Raman spectroscopy and major advances have been made in the required hardware. especially lasers. It is, therefore, recommended that a totally new remote Raman spectrometer be built. If this is not possible, then the best things that can be done are replacing the laser and the electronics.

5.2.1 Laser Replacement

The present ruby laser is unreliable and does not any longer give 2 J per pulse in the red as originally specified. It also only gives two (2) pulses per second. By converting to a frequency doubled Nd:YAG laser it is possible to get 20 - 0.5 J pulses per second which gives more photons. In addition, doubling efficiencies of 35% are readily attainable. Finally, field hardened small low input power Nd:YAG devices are available.

5.2.2 Electronics Update

The present electronics do not give multiple range information nor do they have sufficient dynamic range. In addition, the commercial gated digitizer module presently used in the system has proven to be unreliable. It is recommended that the electronics be replaced with an up-to-date system that has both the dynamic range and capacity to make optimum use of all of the available Raman return signals.

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