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INTERFEROMETRIC STUDIES OF BARIUM RELEASE

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Pittsburgh University

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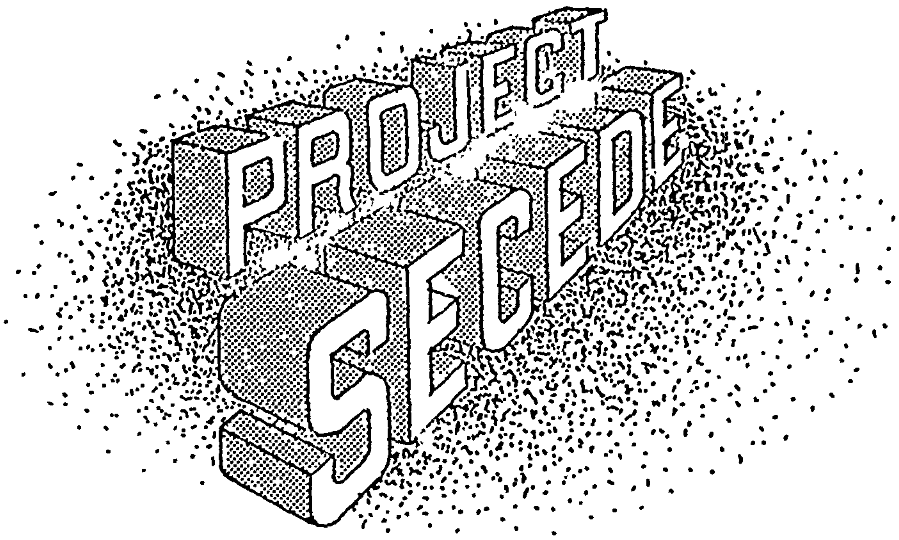

INTERFEROMETRIC STUDIES OF BARIUM RELEASE

University of Pittsburgh

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13. ABSTRACT

The reduction of the Optical Interferometer Secede II data and the design, construction and testing of a rigid mounting cage, pressure housing and thermal housing for a 150 mm aperture Fabry-Perot interferometer are described. Consultation and assistance were provided to R. D. Hake of S.R.I. in the conversion of the interferometer magnetic tape records to ion radiance as a function of spatial scan position in the barium ion cloud. Optical absorption effects at the ion hyperfine wavelength complicate conversion of radiance to ion (and electron) column content, necessitating a radiation transport calculation. The 150 mm Fabry-Perot components were designed and constructed. The assembled instrument is found to maintain high optical resolution in an environment subject to moderate vibration and accelerations.

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INTERFEROMETRIC STUDIES OF BARIUM RELEASES

Manfred A. Biondi

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PUBLICATION REVIEW

This technical report has been reviewed and is approved.

RADC Project Engineer

RADC Contract Engineer

SUMMARY

This report describes the University of Pittsburgh's effort in applying high resolution spectroscopy to the study of the behavior of barium ion clouds of the Secede II series. A telescope augmented, large aperture (100 mm) Fabry-Perot (F-P) interferometer was used to scan the ion cloud with high spatial resolution (~ 100 meters) at an optical frequency for which sunlight is only weakly absorbed and scattered by the barium ions. The scattered intensity at this frequency provides a measure of the barium ion (and, therefore, electron) content along the instantaneous line-of-sight of the instrument. The interferometer was also used to measure the barium ion spectral line profile at 4934Å to assess overall optical absorption (optical depth) effects occurring in filter photographs of the ion clouds and to determine the barium ion temperature (which affects onset of ion cloud instability and striation formation).

The present contract covered two categories of activities: (a) assistance in the reduction of the Secede II optical interferometer data from the magnetic tape records, and (b) design and construction of a suitable rigid mounting cage, pressure housing and thermal housing for 150 mm aperture F-P plates. This latter activity involved design of the 150 mm F-P so that it could act as a substitutional interferometer for the 100 mm F-P in the telescope augmented instrument and at the same time serve as the core unit for a more sensitive, second interferometer if future barium release programs require its use.

The primary responsibility for the optical interferometer Secede II data reduction fell to R. D. Hake of S.R.I. We have provided consultation to and assisted him with the reduction of the magnetic tape records. From these records plots of radiance at the weakly absorbed ion hyperfine frequency have been obtained as a function of spatial scan position in the ion cloud. The data records for events Spruce, Redwood, Plum and Olive have been reduced to varying degrees.

The main problem with the interferometer data is the finding of a much larger absorption at the hyperfine frequency than anticipated on the basis of our Alaska Secede III results. As a result, conversion of ion cloud radiance (at the hyperfine frequency) to barium ion and electron content requires radiation transport calculations. The interferometer results provide qualitative correction factors for conversion of filter photograph radiance to ion content. These corrections prove to be both large and dependent on position in the ion cloud.

As a result of the abundance of interferometer data from four of the Secede II releases, the program to reconstruct data from a faulty magnetic tape track associated with records of the earlier releases was given low priority. This effort will be continued as part of the Pittsburgh Atmospheric Science Institute (ARPA) program.

The design, construction and testing of the elements of the 150 mm aperture F-P have been completed. The rigid mounting cage provides proper F-P plate alignment and maintains this alignment in a "hostile" environment (moderate vibration and acceleration) where normal interferometer mounts fail. The design, which makes use of

a differential screw mechanism to provide the microscopic motions associated with plate alignment in a structure of great alignment rigidity, is described in detail. Tests of the assembled cage, pressure housing and temperature housing indicate that the design objectives have been met. Field application of the 150 mm F-P to studies of chemi-excitation in the upper atmosphere are about to begin under our ARPA-Institute program.

Interferometric Studies of Barium Releases

Manfred A. Biondi

The University of Pittsburgh

Pittsburgh, Pennsylvania

ABSTRACT

The reduction of the Optical Interferometer Secede II data and the design, construction and testing of a rigid mounting cage, pressure housing and thermal housing for a 150 mm aperture Fabry-Perot interferometer are described. Consultation and assistance were provided to R. D. Hake of S.R.I. in the conversion of the interferometer magnetic tape records to ion radiance as a function of spatial scan position in the barium ion cloud. Optical absorption effects at the ion hyperfine wavelength complicated conversion of radiance to ion (and electron) column content, necessitating a radiation transport calculation. The 150 mm Fabry-Perot components were designed and constructed. The assembled instrument is found to maintain high optical resolution in an environment subject to moderate vibration and accelerations.

I. Introduction

The present contract has provided support for the continuation and conclusion of activities of the University of Pittsburgh's Optical Interferometer Experiment associated with the Secede program of barium releases. The tasks under the contract fall into two categories; (a) assistance in the reduction of data obtained with the optical interferometer during the Secede II Florida series and (b) construction of a suitable rigid mounting cage, pressure housing, and thermal housing for the 150 mm aperture, backup Fabry-Perot plates. The latter task had two objectives; to provide a substitutional interferometer for the telescope augmented, 100 mm aperture interferometer used in the Secede II series and to provide the central core unit for a more sensitive, second interferometer of 150 mm aperture in case future programs of barium releases required its use.

As will be detailed in the following sections, the objectives have been achieved, in that we have assisted R. D. Hake of the Stanford Research Institute in his successful reduction of the Optical Interferometer Secede II data, and we have completed and tested a new mounting cage, pressure housing and thermal housing for the 150 mm Fabry-Perot plates which maintains its high-resolution performance even in an environment subject to moderate vibration and acceleration (where normal interferometers fail).

II. Secede II Data Reduction

A. Analysis of Data from Good Magnetic Tape Records

The principal efforts on the part of the various experimental programs have been concentrated on data reduction and analysis for event Spruce of Secede II, for which we obtained a good magnetic tape record of the optical interferometer data. (We also have good records for events

Redwood, Plum and Olive.) Our role in the optical interferometer data reduction for these events has been to provide consultation and assistance to R. D. Hake of S.R.I. during the course of the contract. Some of the results of the data reduction for events Spruce, Redwood, Plum and Olive are contained in RADC TR-72-242, "Secede II: Fabry-Perot Interferometer Data", by R. D. Hake.

The optical interferometer performed up to its design specifications during the Secede II observations, and conversion of the magnetic tape data to plots of radiance at the ion hyperfine wavelength as a function of spatial scan position has proceeded smoothly. The main problem encountered in the data reduction has stemmed from our finding that the Secede II events in Florida exhibited stronger optical absorption effects than did corresponding releases during Secede III in Alaska. This increased line-of-sight absorption evidently resulted from the smaller ion-neutral relative velocity in Florida than in Alaska, with a consequent piling-up of the ionization in a more restricted volume of the ionosphere and hence a larger barium ion column density than anticipated.

The overall effect of the increased ion column density is the occurrence of significant optical absorption at the wavelength of the weak hyperfine ion line component (which was to be used as a direct measure of ion column comment without need for optical depth corrections). While this absorption effect could have been reduced by optimizing the choice of optical interferometer site (without regard for co-location requirements with the r-f experiments), it appears that for these release sizes in mid-latitudes there is no way of completely avoiding persistent optical depth effects at the 4934Å ion hyperfine line wavelength. If future barium releases involve the use of optical interferometers for ion column content determinations, first priority should be given to location of the interferometer to provide sun-to-ion cloud and ion cloud-to-observor paths which minimize the optical depth; then proximity to related experiments should be considered.

Our Secede II hyperfine line radiance data are being converted to barium ion (and electron) column densities by a simplified radiation transport calculation applied to an idealized ion cloud model by R. D. Hake. Again, we have provided consultation on these calculations. It is clear that a realistic model of the post-striation ion cloud with its many shadowing "rods" or "slabs" of ions is too complicated for a quantitative radiation transport calculation.

An important result of these interferometric measurements and analyses is that they demonstrate that filter photographic records of the ion cloud are even more qualitative in providing ion column content information than had been expected on the basis of the Secede III Alaska data analyses. Also, the interferometer data show that the correction factors which must be applied to the photographic records to convert integrated radiance to ion column content vary markedly from point-to-point in the ion cloud.

B. Recovery of Data from Faulty Magnetic Tape Records

As a result of the availability of good magnetic tape data records for several events of the Secede II series and of the above-mentioned optical-depth complications in the data analysis, the program to attempt recovery of data from the faulty magnetic tapes of the early Secede II events was given lower priority. This program is attempting reconstruction of data from a faulty tape track by use of our small Xerox CF16 computer which is installed at the University's Airglow Observatory. Since the barium release data are of interest not only to the Secede program but also to the upper atmosphere research programs of our Pittsburgh Atmospheric Sciences Institute (ARPA), we are continuing, as an Institute program, construction of the computer interfacing elements which will permit data unpacking from the Secede II Incremental Tape records and transfer to the computer's Kennedy Model 8107 Continuous Tape Recorder in a language compatible with the Xerox computer.

III. Design, Construction and Testing of the 150 mm Aperture Fabry-Perot

A major effort under the present contract has been expended in refining the design of the rigid mounting cage for the Fabry-Perot (F-P) plates. This cage maintains accurate alignment of the plates for high resolution measurements in a "hostile" environment (i.e., one in which moderate vibration and accelerations occur). As a result of time constraints before the Secede II series, the rigid cage for the 100 mm F-P used in the telescope-augmented mount had to be constructed and put into operation without exhaustive testing. Subsequent to Secede II, some problems with the 100 mm F-P cage were noted and traced to improper operation of one of the plate support rails. This problem has been corrected in the 100 mm cage and has led to a design change in the 150 mm cage.

A simplified drawing of the rigid cage for the 150 mm aperture F-P is given in Fig. 1 (the 100 mm F-P cage is very similar in design). The separation between the F-P plates $P\ell_1$ and $P\ell_2$ is determined by three invar spacer pins S disposed 120° apart in an invar ring. (The three pins are hand lapped to be equal in length to within $\leq$ 5 millionths of an inch.) The plates rest on two felt-lined pillow blocks B which make point contact with two support rails R and are mounted with their axes horizontal. (In this way plate bowing due to alignment stresses and gravitational sag is minimized.) The support rails are rigidly attached to the rear ring of the cage Re and to a small ring at the front.

The accurate parallel alignment of the plates is achieved by lightly compressing the spacer pins S by means of a differential screw mechanism. This screw mechanism is also the heart of the rigid cage structure. With the rear compression pins P screwed back slightly from their final locked positions, the F-P plates and spacer are loaded into the cage with the front ring Fr removed. The three differential screws D (one for each spacer pin) are then threaded into the front ring Fr and advanced until each compresses moderately its encompassing thin-walled (.010" thick) invar tube T. The rear compression pins are then screwed forward until, as evidenced by the sudden change in the optical interference pattern (viewed on a helium light table), they make contact with the rear F-P plate $P\ell_2$ and compress the spacer pins. Each spacer pin is compressed ~ 10 fringes and each rear pin then locked by a locking nut L. In this way the plates are "rough-aligned" - i.e., rendered parallel to within substantially less than one fringe.

Final, accurate alignment is achieved by rotating the appropriate differential screw D to reduce or increase the adjacent spacer pin compression. A sufficiently fine motion of the differential screw has been attained by using a 40 per inch thread at the front and a 41 per inch thread at the rear. Friction between the invar screw and the invar front and rear rings causes the parallelism adjustment to occur in small, discrete steps rather than completely smoothly as noted with the usual spring loaded compression pins; however, once alignment is achieved it maintains itself under vibration and acceleration loads for long periods.

The whole cage is mounted in a pressure housing by three low-thermal-conductivity struts which attach to the rear plate Re and to the rear wall of the pressure housing (which also contains the output lens). The pressure housing is insulated and in turn is mounted inside a temperature regulated housing. In this way the aligned Fabry-Perot plates are kept in an inert gas (argon) environment and are subjected to a minimum of temperature variation over extended periods of time.

The mounting cage, pressure housing, and thermal housing were completed during the course of the contract, and the new 150 mm aperture F-P plates installed. The supplier (Perkin-Elmer) tested the plates before shipping and certified them to be flat-matched to $\lambda/70$ (at $\lambda = 6328\text{Å}$) over the 150 mm aperture. This leads to a maximum "defect finesse" of the plates in an ideal mounting at optimum alignment of $N_D = 35$.

With reflecting and output aperture finesses matched to this defect finesse (to maximize optical sensitivity and resolving power) an overall instrumental finesse of ~ 21 should be attained. Our tests of the mounted plates gave a finesse of this value. When a smaller exit aperture was used (thereby increasing the output aperture finesse) an overall instrumental finesse of ~ 25 was obtained. This finesse is consistent with the specified plate flatness and specified reflectivity of the plate coatings.

Thus, the 150 mm aperture Fabry-Perot is now in a form where it can be used substitutionally for the 100 mm telescope augmented Fabry-Perot or can serve as the core unit of an interferometer of somewhat greater than twice the sensitivity of the 100 mm unit. This added sensitivity permits increased spatial resolution (down to 0.2 mrad, i.e. 40 m at 200 km slant range if augmented by a 24" telescope) or observation of more diffuse barium clouds. We hope to exploit this added sensitivity in studies of chemi-excitation mechanisms in the upper atmosphere by night-glow measurements carried out under our ARPA Institute program.

Illustrations

Fig. 1 Scale drawing of the rigid mounting cage for the 150 mm aperture Fabry-Perot plates.

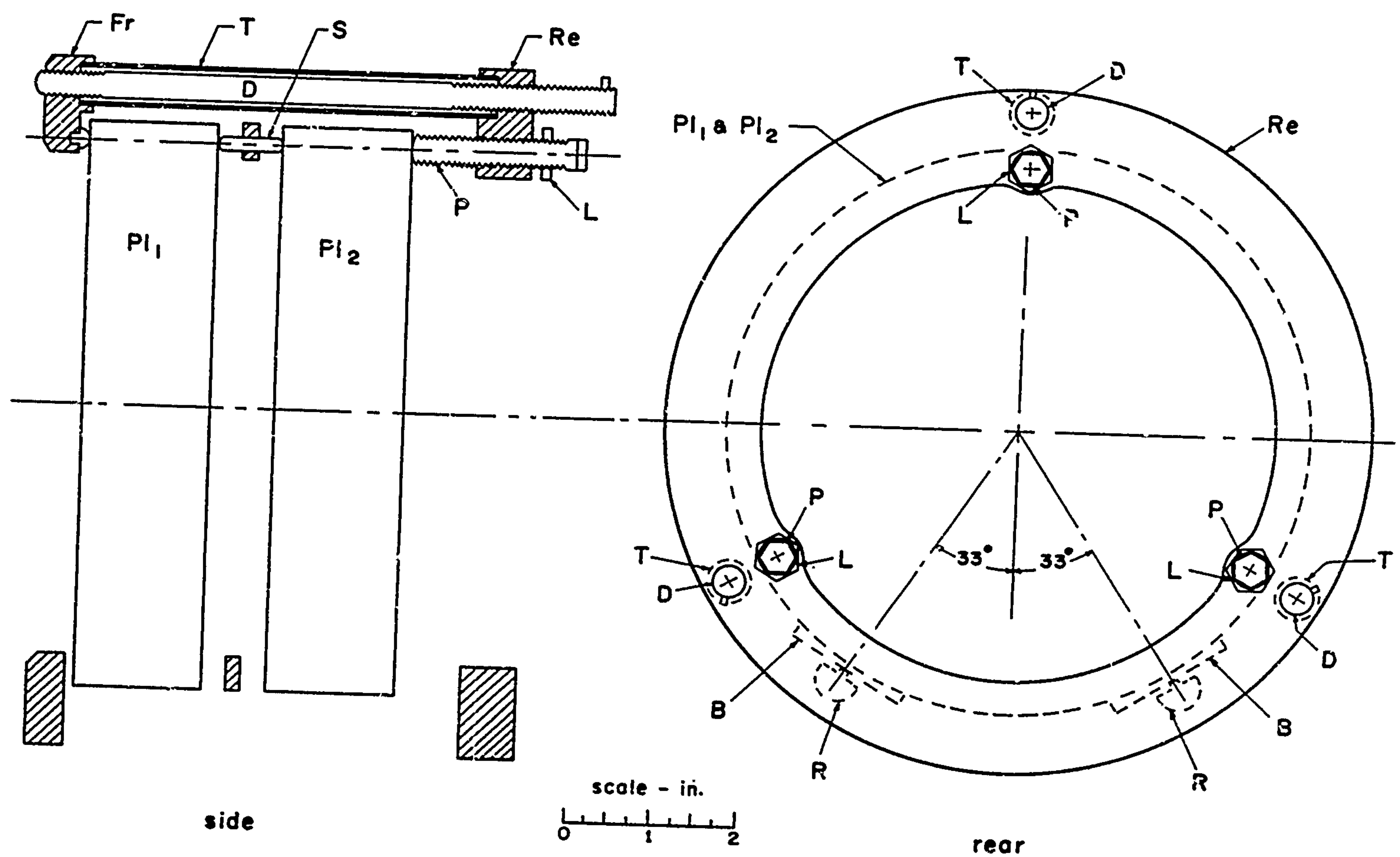
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Figure 1