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Report No. IITRI-A6141-QR1
(Quarterly Status Report)

A HIGH ALTITUDE MEASUREMENT TO DETERMINE THE RATIO OF DEUTERIUM TO HYDROGEN IN THE SOLAR ATMOSPHERE

National Aeronautics and Space Administration
Office of Space Science and Applications
Washington, D. C. 20546

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21 October 1965

National Aeronautics and Space Administration
Office of Grants and Research Contracts
Office of Space Science and Applications
Washington, D. C. 20546

Attention: Miss Winnie M. Morgan
Technical Reports Officer

Subject: Report No. IITRI-A6141-QR1 (Quarterly Status Report)
1 June 1965 through 31 August 1965
"A High Altitude Measurement to Determine the Ratio of Deuterium to Hydrogen in the Solar Atmosphere"
Contract No. NASr 65(13)/14-003-913
IITRI Project A6141

Gentlemen:

This is a Quarterly Status Report covering the period 1 June 1965 to 31 August 1965 on NASA Contract NASr 65(13)/14-003-913.

Due to the fact that the equipment to be used on the experiment was unavoidably detained in the Pacific on another program, alterations for the present program could not commence until August. This delay is the reason for the grant of a time extension to the program until December 30, 1965. (See letter from T.L.K. Smull, Contracting Officer, Ref. SC/14-003-913-VPH:gm, dated 30 September 1965.)

Itemized below are several aspects of the work which have been initiated on the program:-

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A HIGH ALTITUDE MEASUREMENT TO DETERMINE THE RATIO OF DEUTERIUM TO HYDROGEN IN THE SOLAR ATMOSPHERE

1 June 1965 to 31 August 1965

Contract No. NASr 65(13)/14-003-913
IITRI Project No. A6141

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for

National Aeronautics and Space Administration
Office of Space Science and Applications
Washington, D. C. 20546

21 October 1965

1. A study of the off-band suppression available with various combinations of Fabry-Perot interferometers and forefilters has resulted in a decision to design the system to comprise of:-

(a) A 10A halfwidth forefilter centered on H_α at 6562.8A;

(b) A scanning Fabry-Perot interferometer of 6A Free Spectral Range and a finesse of 30, giving a resolution of 0.2A;

(c) A second scanning Fabry-Perot interferometer of 13.75A Free Spectral Range and a finesse of 30, giving a resolution of 0.46A.

When used in tandem these interferometers will have an effective instrumental function given by

$$I = \left[\frac{T_1^2}{(1-R_1)^2}\right]\left[\frac{T_2^2}{(1-R_2)^2}\right]\left[\frac{1}{(1+F_1 \text{ Sin}^2 \delta_1/2)\ (1+F_2 \text{ Sin}^2 \delta_2/2)}\right]$$

where T_1, T_2 are the respective transmissions,

R_1, R_2 are the respective reflectances of the interferometer plates, and

F_1, F_2 are the respective finesses of the interferometers.

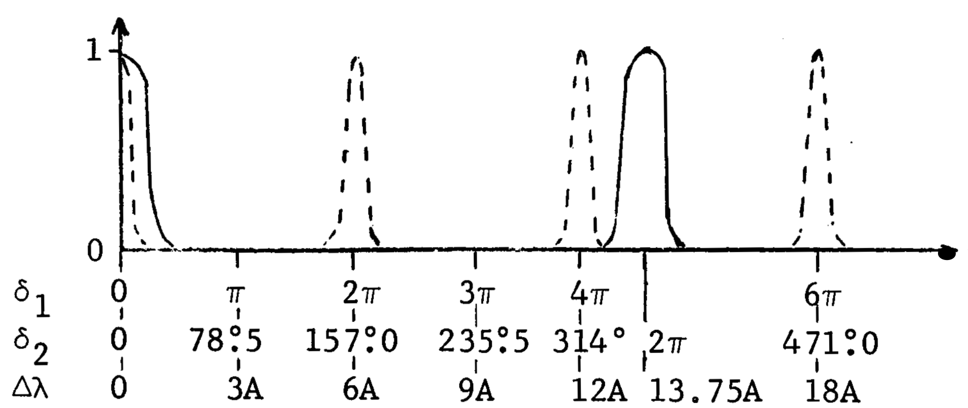
Table 1 below shows the relative magnitude of the interferometer combination for several selected order intervals.

Table 1. Transmittance Function for Two Fabry-Perot Interferometers

		A		B	
$\Delta\lambda$	δ_1	$(1+F_1 \sin^2 \delta_1/2)$	δ_2	$(1+F_2 \sin^2 \delta_2/2)$	$\frac{1}{AB}$
3A	π	2.4×10^3	78.5	9.8×10^2	4.25×10^{-7}
6A	2π	1	157.0	2.3×10^3	4.35×10^{-4}
9A	3π	2.4×10^3	235.5	2.04×10^3	2.08×10^{-7}
12A	4π	1	314.0	3.66×10^2	2.74×10^{-3}
18A	6π	1	471.0	1.63×10^3	6.14×10^{-4}

$\frac{1}{AB}$ gives the transmission of the combination relative to the maximum transmission at the common peak wavelength.

$\Delta\lambda$ is the interval expressed in Angstrom units as shown below:



When the instrumental function of the combination is combined with the narrow pass forefilter the result is the overall transmission of the complete system. Table 2 shows the resulting system instrumental function. $T(\Delta\lambda)$ is the normalized transmission of the forefilter whose halfwidth is 10A.

Table 2. Transmittance Function for Two Interferometers and a Forefilter of Halfwidth 10A

$\Delta\lambda$	$\frac{1}{AB}$	$T(\Delta\lambda)$	$\frac{1}{AB} T(\Delta\lambda)$
3A	4.25×10^{-7}	0.81	3.4×10^{-7}
6A	4.35×10^{-4}	0.38	1.65×10^{-4}
9A	2.08×10^{-7}	0.10	2.08×10^{-8}
12A	2.74×10^{-3}	0.03	8.2×10^{-5}
18A	6.14×10^{-4}	0.008	4.9×10^{-5}

2. When two or more Fabry-Perot interferometers are used in tandem there exist spurious maxima, or "ghosts" in the intensity pattern due to reflections between parallel faces

of the different interferometers. This so-called coupling and its prevention has been treated in detail recently by J. Schwider (Entkopplungsmoglichkeiten von Fabry-Perot Interferometern, Optica Acta, Vol. 12, No. 1, p.65, Jan. 1965.) The method employed in this work is somewhat similar to that of Geusic and Scovil referred to by Schwider. Figure 1 shows the arrangement used.

3. With the method of scanning employed in this work, viz. magnetostriction, a problem arises in that it is difficult to maintain the transmission peaks of the two interferometers exactly in alignment. This problem is being investigated at the moment and an apparently promising approach is being tried. This consists of using a common linear ramp generator for the two interferometers, followed by two low noise feedback amplifiers, one for each interferometer. The feedback resistor in each amplifier is replaced by a temperature compensated strain gauge placed across the interferometer gap so that any tendency for the spacing change between the plates to depart from linearity is counteracted by the negative feedback effect. Possible sources of non-linearity are thermal drifts and non-linearity of the magnetostrictive coefficient. Figure 2 shows a schematic representation of the system.

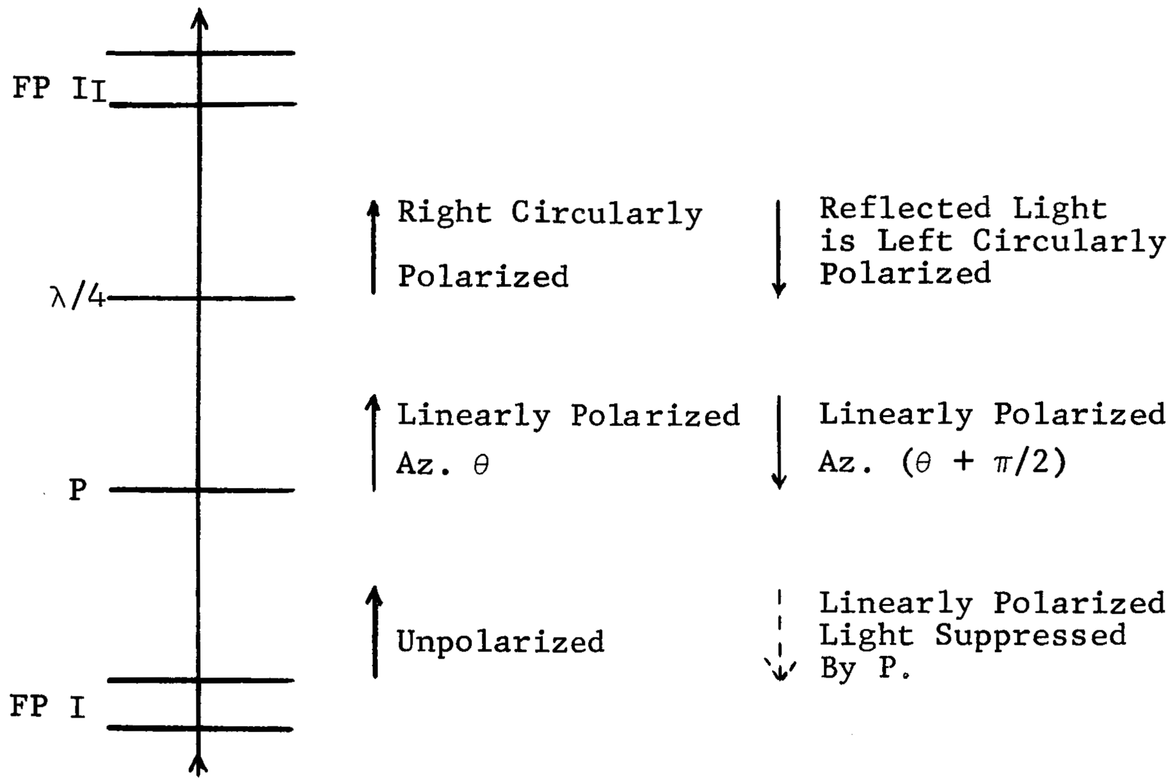


Figure 1, showing arrangement used to prevent coupling between Fabry-Perot interferometers in tandem.

ELECTRICAL BLOCK DIAGRAM FOR 2 INTERFEROMETER SYSTEM

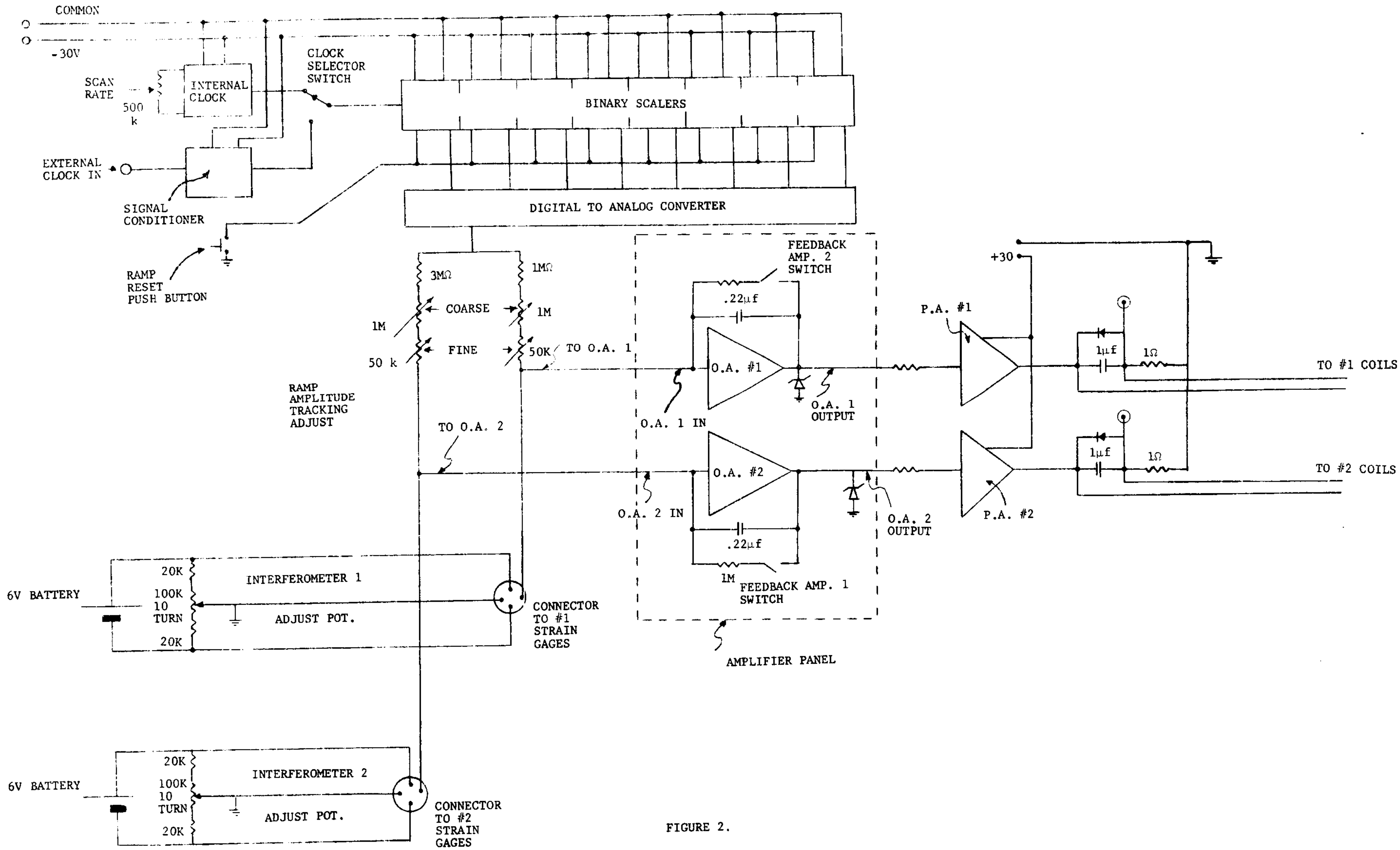


FIGURE 2.

4. The desired accuracy of measurement in this program is 0.05%. This requires that the transmission characteristics of all elements in the optical train be known to better than 0.05%. At present no commercially available spectrophotometer gives better than 0.2% accuracy so that a research effort is required to evaluate the transmission of the forefilter to the desired accuracy. It is intended to do this using the Fabry-Perot interferometer system and a highly accurate ratio type digital voltmeter. This voltmeter is the Model 5600 produced by Dana Laboratories, Inc. which has an accuracy of 1 part in 10^4. An outline of the system to perform this measurement of the transmission function of the forefilter is shown in Figure 3.

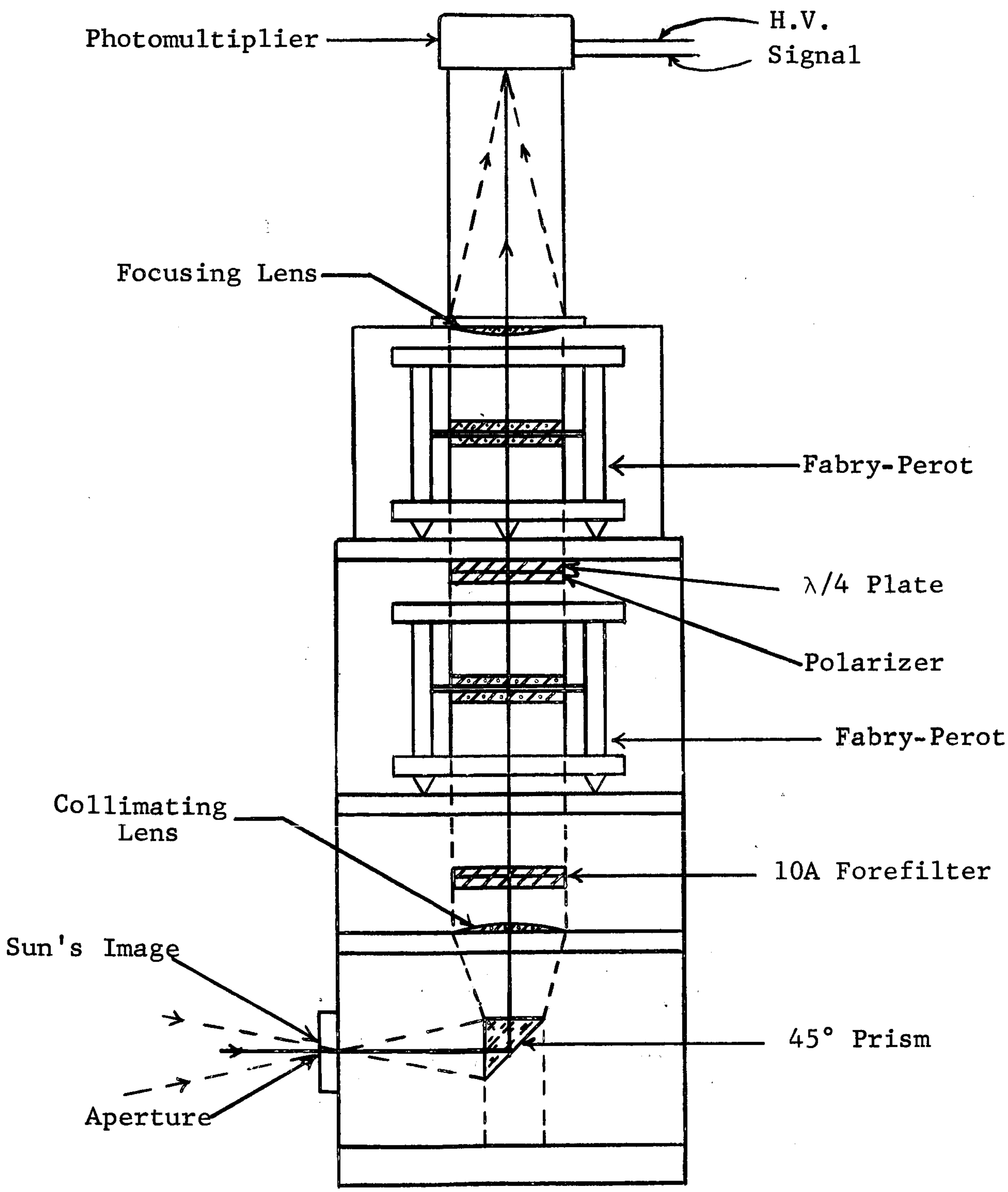


Figure 3. Showing present arrangement of two Fabry-Perot Interferometers in tandem.

In summary, the progress of the program is satisfactory although research has brought to light two regions of difficulty. These are, (1) the noise level of the feedback amplifiers which limits the accuracy of wavelength setting; (2) the establishment of the transmission function of the forefilter to the desired accuracy. It is hoped to overcome these difficulties and perform a ground based measurement of the solar H_α and H_β lines sometime in December of this year.

Respectfully submitted:
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