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TITLE: MULTI-CHORD, NEAR INFRARED INTERFEROMETERS FOR THE CTX AND ZT-40M EXPERIMENTS

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AUTHOR(S): Ernest W. Newman, CTR-5
C. J. Buchenauer, CTR-2
Hiroshi W. Hoida, CTR-5

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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Multi-Chord, Near Infrared Interferometers for the CTX and ZT-40M Experiments

E. V. Newman, C. J. Buchenauer, and H. V. Hoida,

Los Alamos National Laboratory, Los Alamos, New Mexico 87545

A versatile, multi-chord CO_2 interferometer design with a wide dynamic range is adapted to several different experiments. The systems are double-pass, Mach-Zehnder, heterodyne, interferometers, that employ a single germanium Bragg cell and $2^{n+1}-1$ (n an integer) 50% beamsplitters to produce 2^n interferometer chords, and a single reference beam with matched optical path lengths. Heterodyne signals detected with room-temperature HgCdTe photo-resistors are demodulated with digital phase detectors that can track several fringes per μsec. The real-time electron density readouts provide a considerable savings in ADC channels and computation time when compared with quadrature phase detection schemes. High reliability is achieved with a temperature controlled wave-guide CO_2 laser operating on a single mode at intermittent duty. The CTX instrument has been operating with 8 chords since March, 1984. The ZT-40M instrument, which is under construction, employs a second wavelength to correct for room vibrations in the 0.01 fringe density range.

INTRODUCTION

A versatile multichord heterodyne CO_2 interferometer design is presented. The design is adaptable to several different experiments and has been implemented on CTX. The systems provide a wide dynamic range, real time density readout, high reliability and a minimal number of optical components.

I. DESCRIPTION

In Fig. 1, matched scene and reference beam path lengths eliminate measurement errors caused by laser frequency fluctuations due to acoustic noise in the environment, mode pulling caused by stray radiation reentering the laser, and by fluctuations in the laser discharge. The double pass reference beam is focussed through the plasma onto a plane return mirror with a Rayleigh range of focus extending through the plasma. This minimizes alignment sensitivity of the remote scene beam mirrors, fringe contrast sensitivity to a point like beam deflection within the plasma, and the scene beam width within the plasma. A second wavelength laser to compensate for vibrations is optional.

The basic design for an expandable multi-chord system is shown in Fig. 2. The scene and reference beams travel side by side and are divided by an array of 50% beam splitters which is used to form 2^n interferometer chords. The beam splitters are used at near normal incidence to preserve the polarization state and to minimize errors caused by torsional modes. The common reference beam leg matches the path length of all scene beams.

The wave-guide CO_2 laser is temperature controlled and operated in a single mode. It is pulsed on during the experiment. A germanium Bragg cell doppler shifts the frequency of the reference beam by the acoustic drive frequency f (40 MHz). Heterodyne signals are detected with room temperature HgCdTe photo-resistors and are demodulated by a digital phase detector (Fig. 3) which was developed to measure the phase shift between the detected RF signal and the RF drive. The demodulator can track several fringes per μsec. The real time readout, when compared to conventional quadrature phase detection schemes, results in a considerable savings in ADC channels, computation time and computer memory. The phase demodulator operates on the principle of a zero crossing time measurement and has a range of $2\pi N$. The experimental requirements are met by choosing N appropriately, and by presetting the initial conditions of the counters before the shot so that the output remains in the linear range during the measurement.

The CTX instrument (Fig. 4) has been operating with eight chords since March, 1984.

The ZT-40M instrument (Fig. 5),which is under construction, employs a second wavelength to correct for room vibrations to the 0.01 fringe level.

I.. EXPERIMENTAL DATA

Data from the CTX interferometer is shown in Fig.6. The raw signals are displayed as a function of time and impact parameter. The signals are inverted using a subtraction algorithm resulting in a "discrete" inversion (Fig. 7).

Fig. 1. Basic single-chord interferometer.

Fig. 2. Multi-chord interferometer.

Fig. 3. 2π digital phase detector

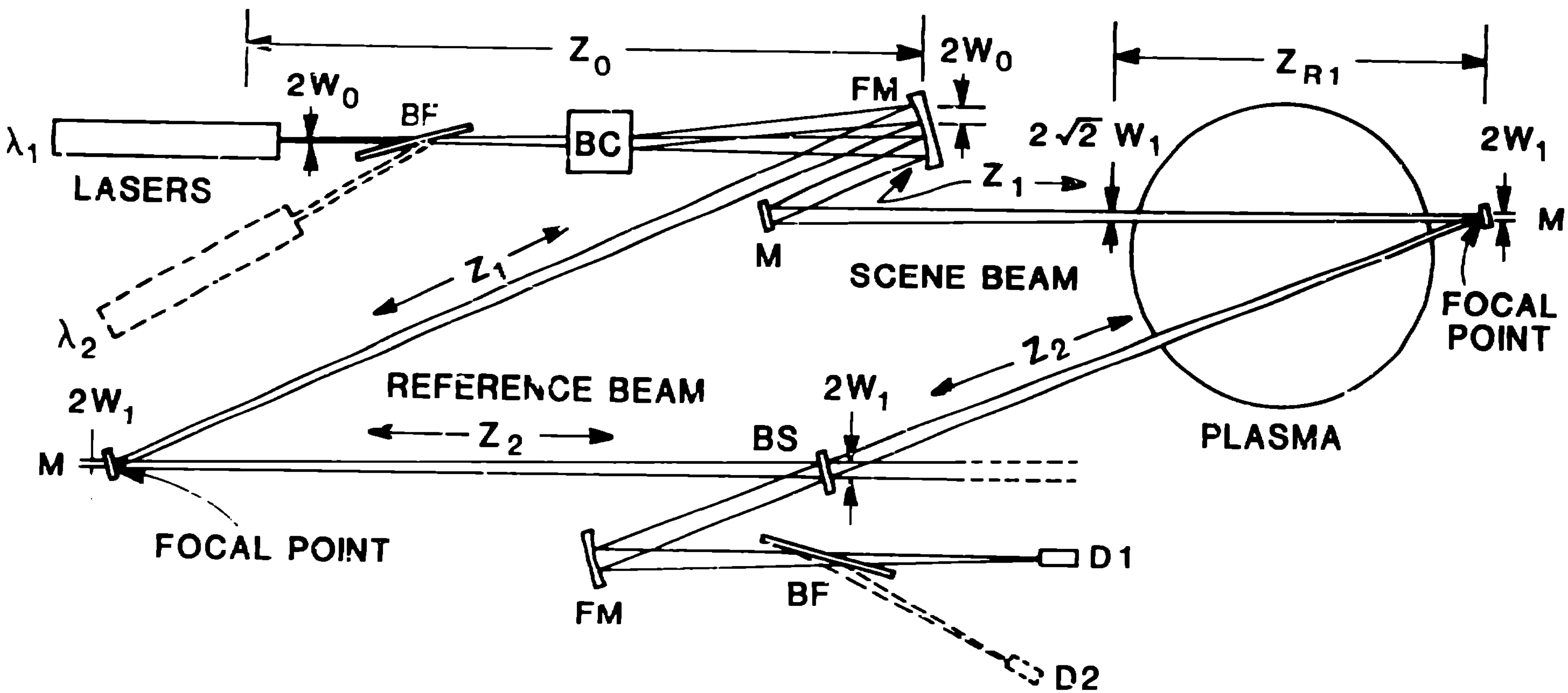
Fig. 4. Eight-chord infrared interferometer for the CTX experiment.

Fig. 5. Two-wavelength eight-chord interferometer for the ZT-40M experiment.

Fig. 6. Average line integrated, unreduced, density time histories for different radial positions.

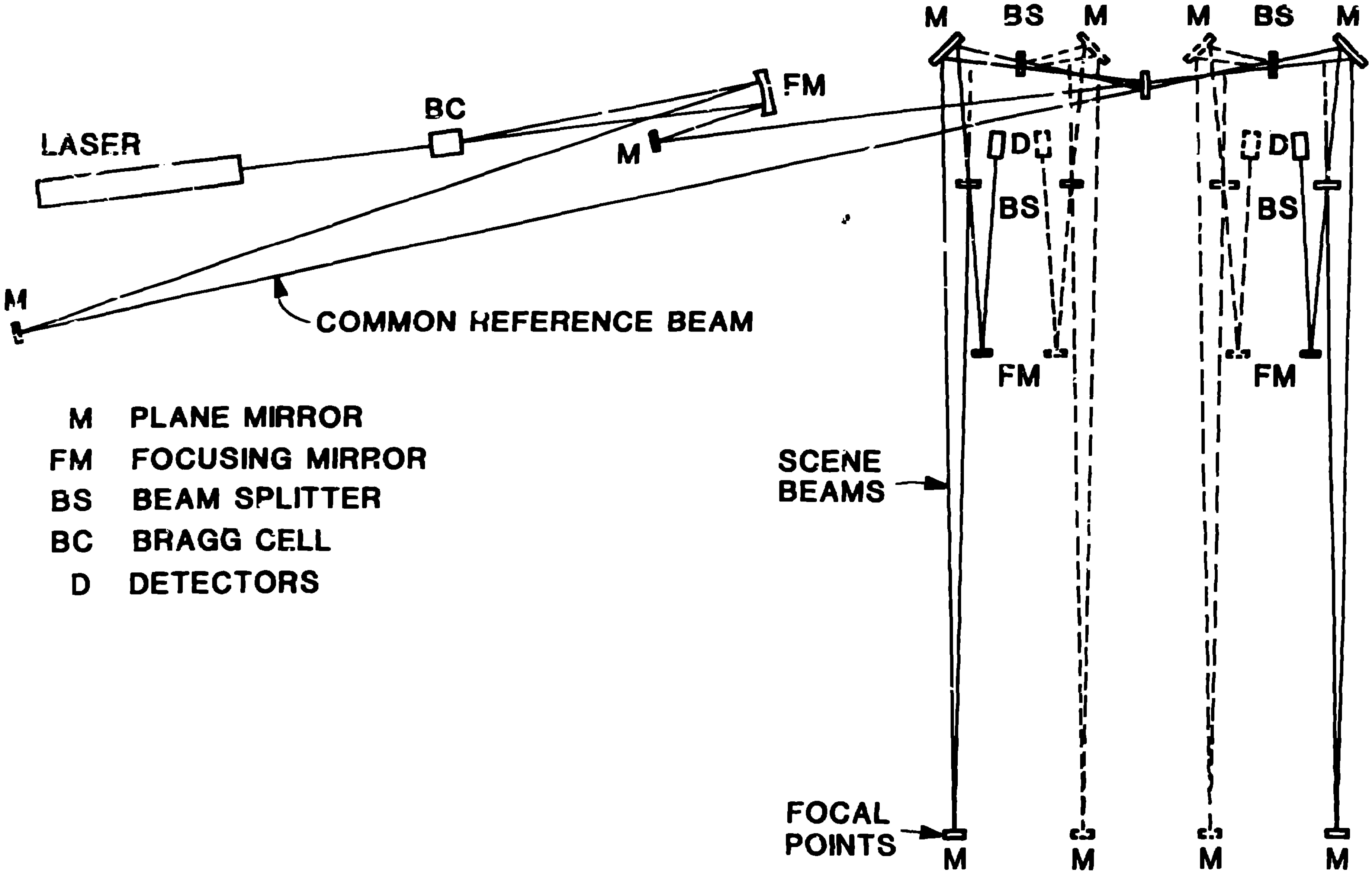
Fig. 7. Inverted density time histories for different radial positions. The discrete inversion was performed assuming cylindrical symmetry.

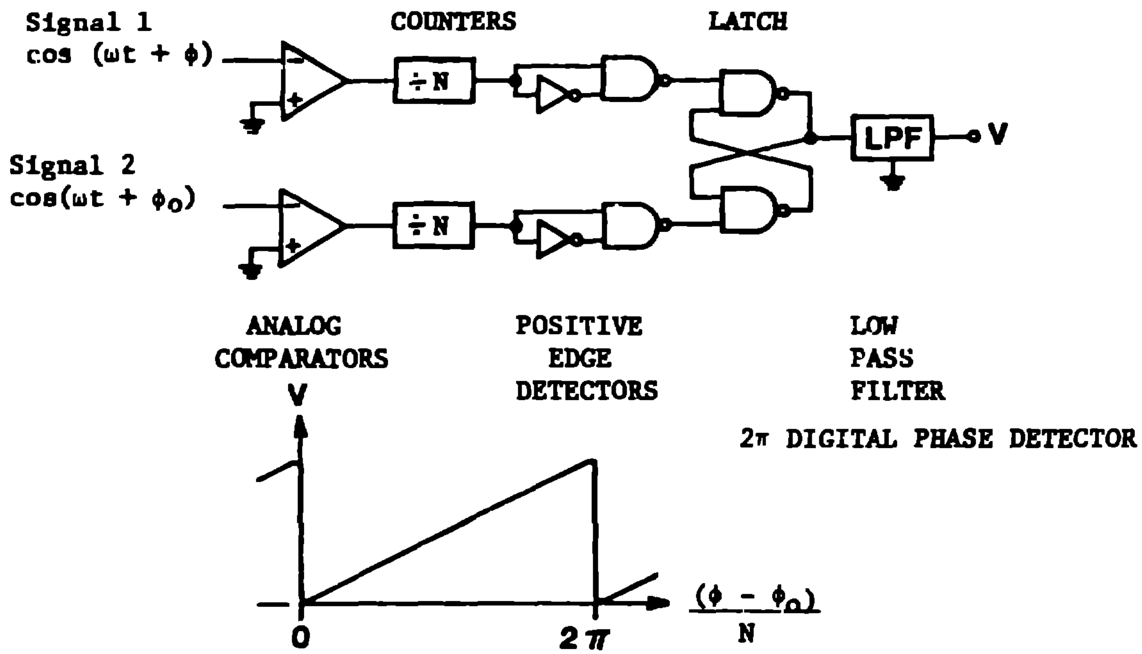
BASIC SINGLE-CHORD INTERFEROMETER
(- - - - TWO WAVELENGTH OPTION)



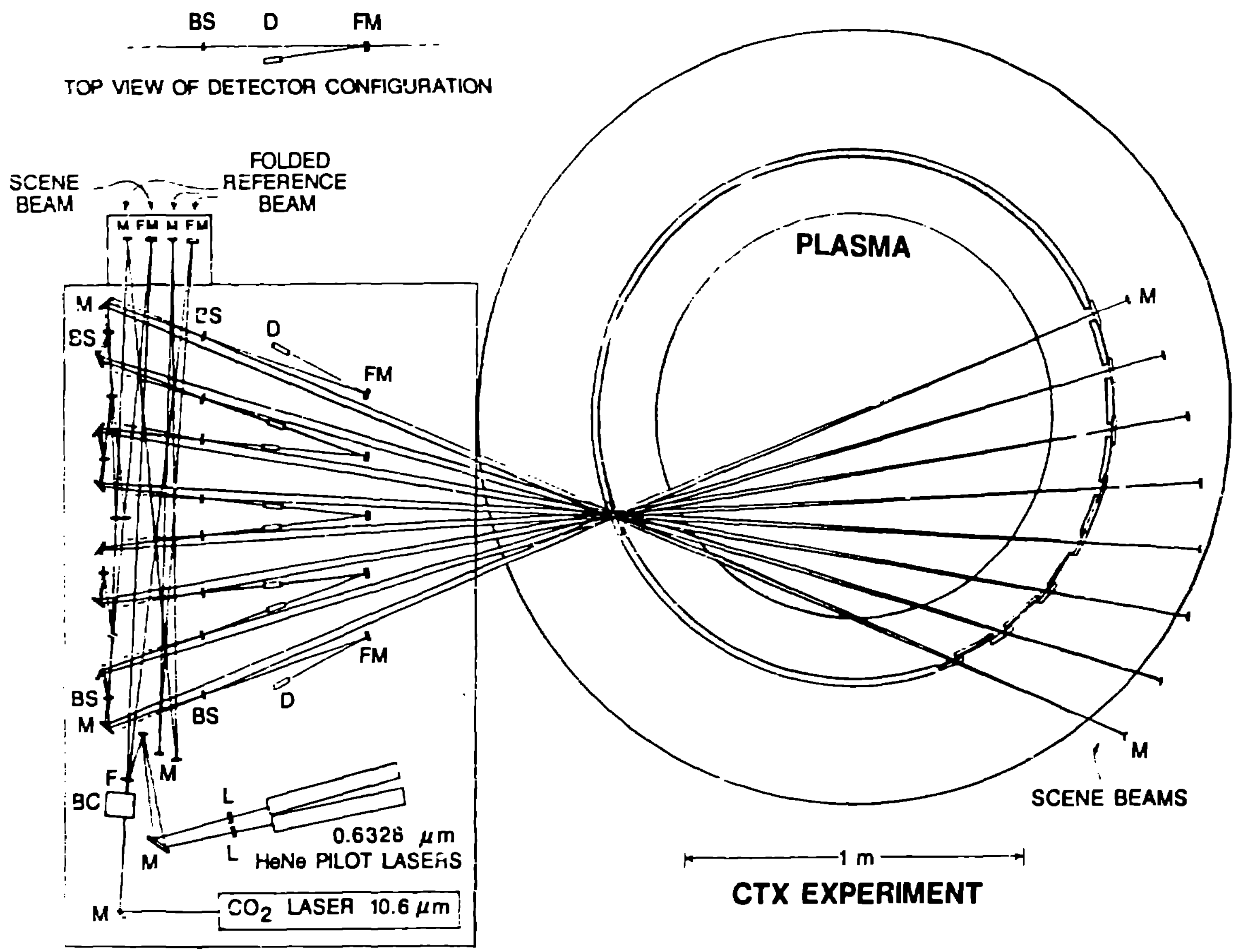
M	PLANE MIRROR	Z's	PATH LENGTHS
FM	FOCUSING MIRROR	D1	DETECTOR FOR λ_1
BF	BREWSTER FLAT	D2	DETECTOR FOR λ_2
BS	BEAM SPLITTER	W's	BEAM RADIUS
BC	BRAGG CELL		

MULTI-CHORD INTERFEROMETER DESIGN SCHEME



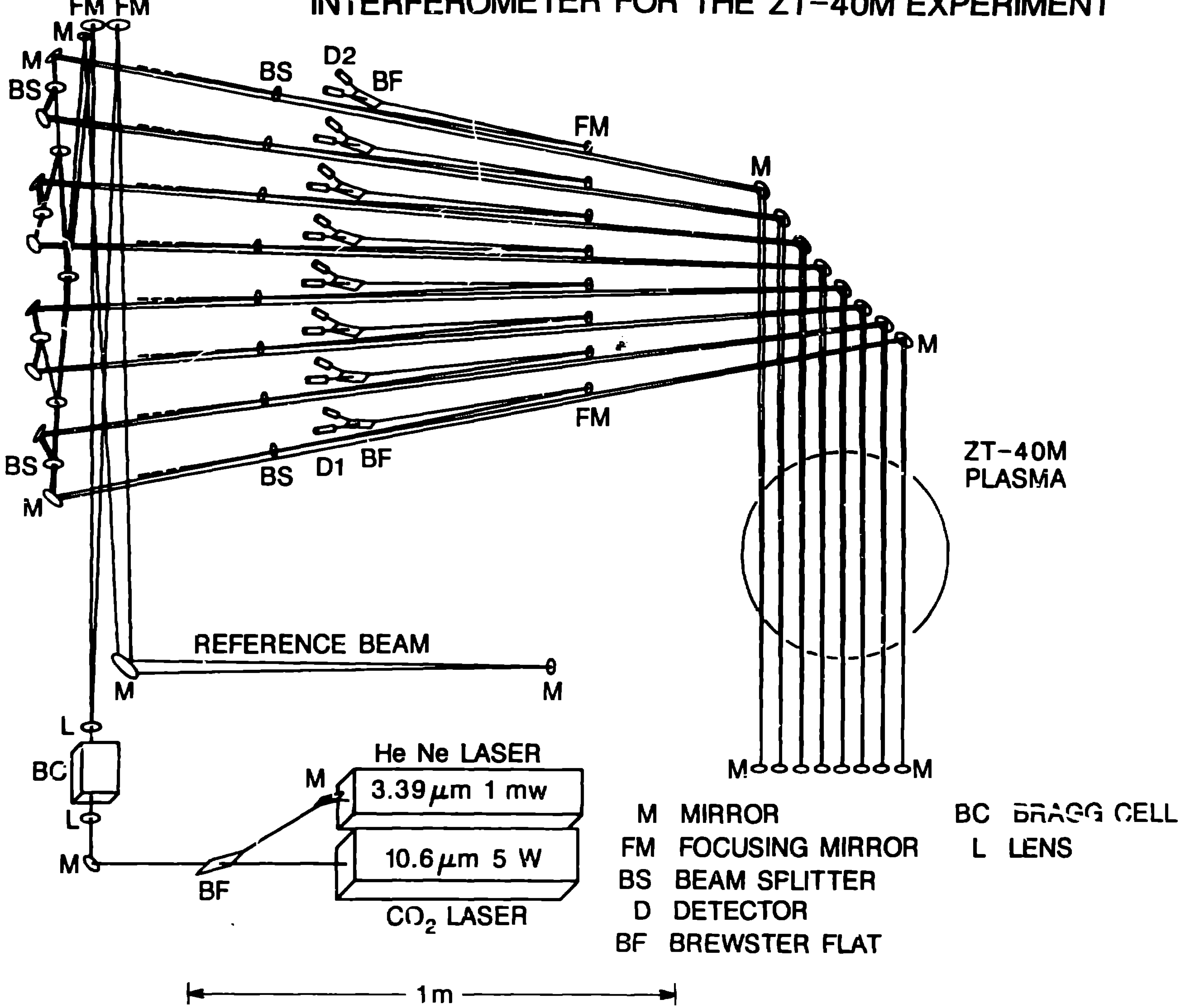


A digital phase detection circuit

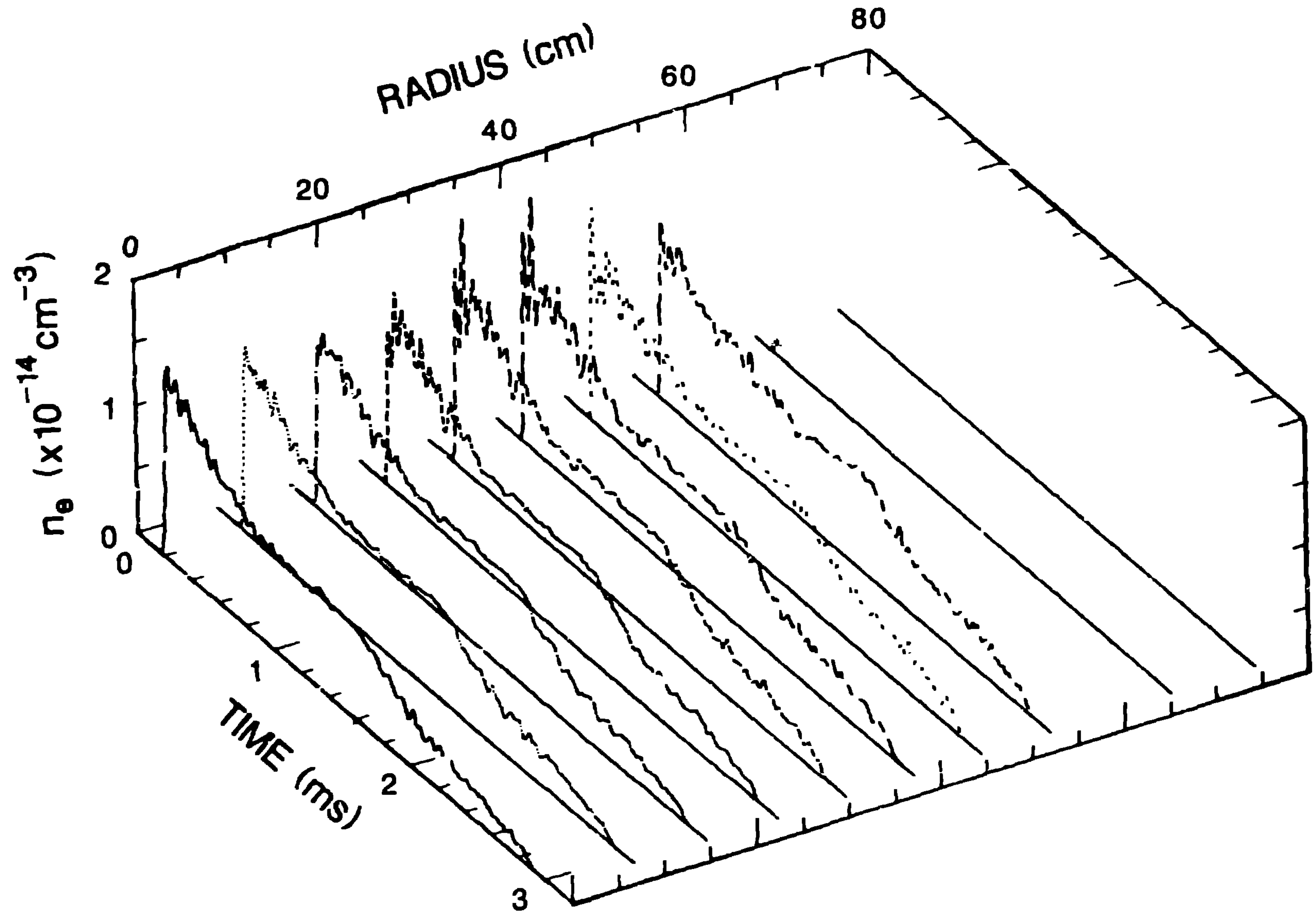


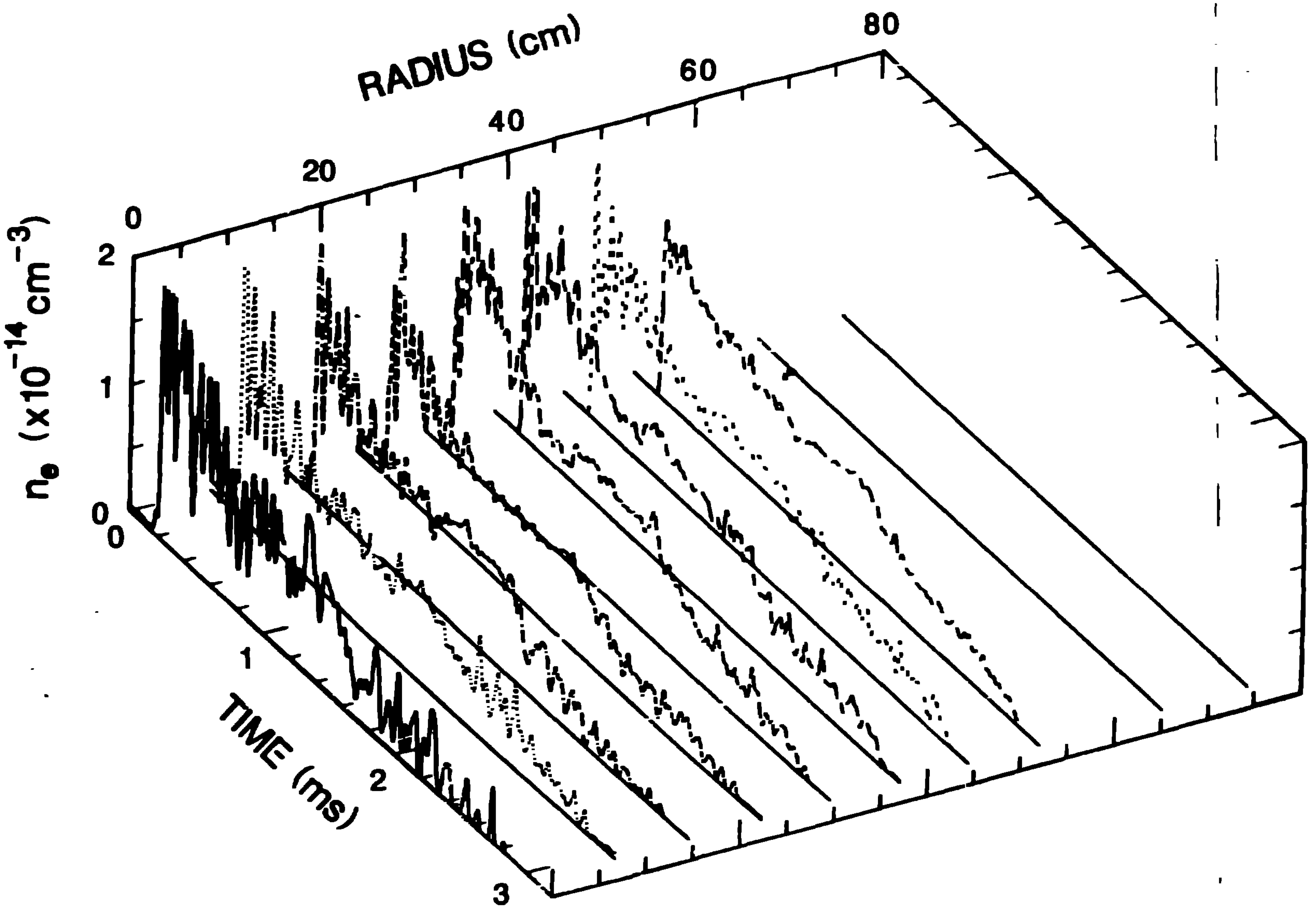
BC BRAGG CELL
BS BEAM SPLITTER
D DETECTOR
F COLOR SEPARATION FILTER
FM FOCUSING MIRROR
L LENS
M MIRROR

TWO-WAVELENGTH EIGHT-CHORD INTERFEROMETER FOR THE ZT-40M EXPERIMENT



OBLIQUE VIEW OF OPTICS


RADIUS (cm)
0
20
40
60
80
n_e ($\times10^{-14}$ cm^{-3})
0
1
2
TIME (ms)
0
1
2
3



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