A NEW MULTI-POINT, MULTI-PULSE THOMSON SCATTERING SYSTEM FOR THE MST RFP

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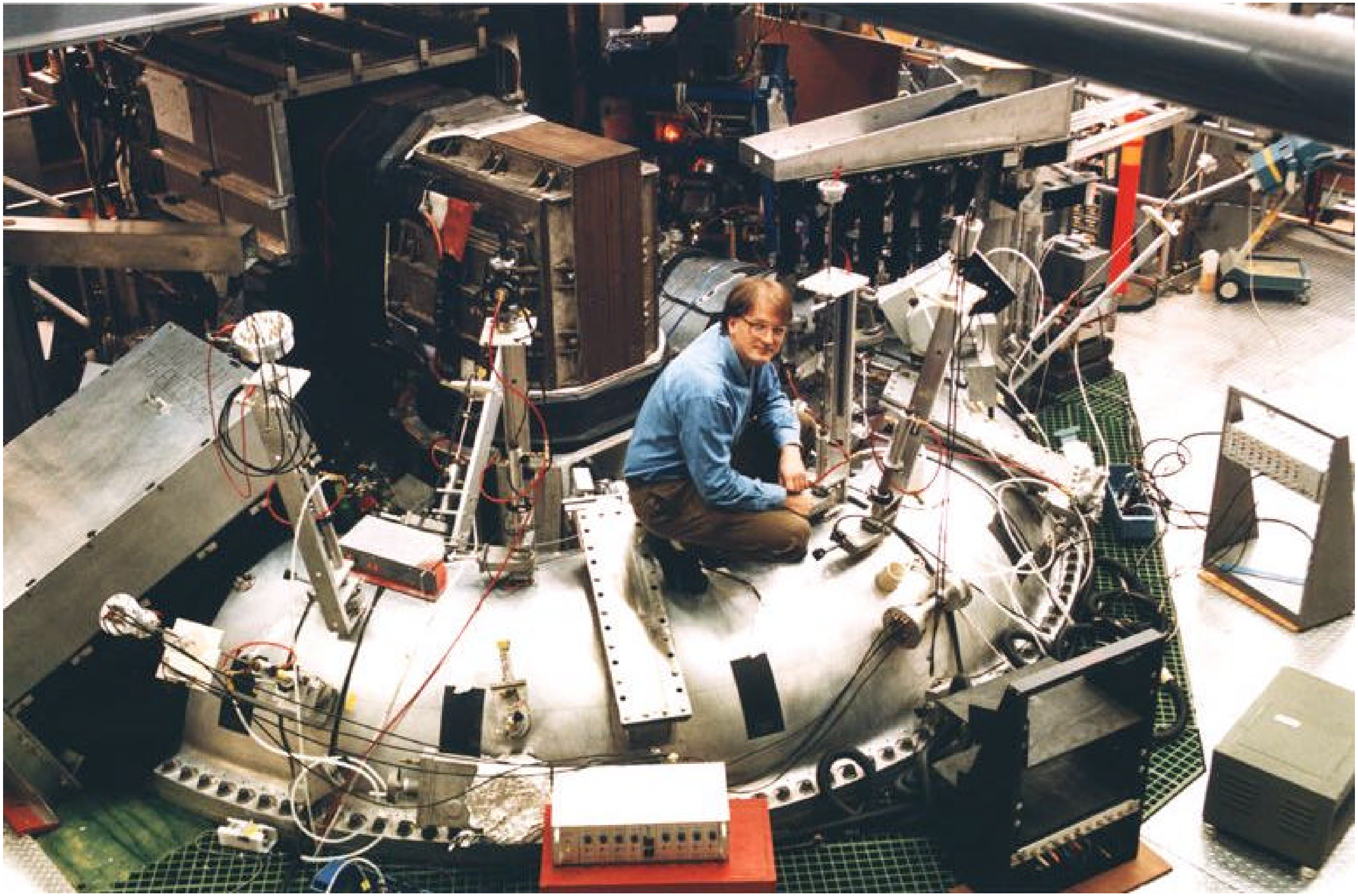
We are building a new Thomson scattering diagnostic system to measure electron temperature and density on the MST reversed-field pinch experiment. This system is being designed to produce accurate single-shot measurements for 10 eV < T_e < 2 keV at electron densities $\geq 10^{18}$ m^{-3}. Scattered light will be simultaneously recorded from 20 radial locations across the 50 cm minor radius of the plasma. Multi-pulse capability will be provided by two identical Nd:YAG pulsed lasers whose trigger timing can be independently varied. This will allow several combinations of input energy and pulse timing during an MST discharge, ranging from one 4 J pulse for increased accuracy during low density operation to 1 J pulses at 100 Hz for temporal evolution measurements. Scattered light will be collected by a custom deep-focus lens and coupled by optical fiber to 20 identical filter polychromators. These polychromators are being manufactured by General Atomics and use silicon avalanche photodiode detectors [T. N. Carlstrom *et al.*, Rev. Sci. Instrum. **6**1, 2858 (1990)]. Each polychromator contains three wavelength channels to allow determination of T_e, plus one channel at the laser wavelength to allow calibration using Rayleigh scattering for measurement of n_e. System control and data acquisition will be done with a single dedicated personal computer.

Madison Symmetric Torus



MST Reversed Field Pinch

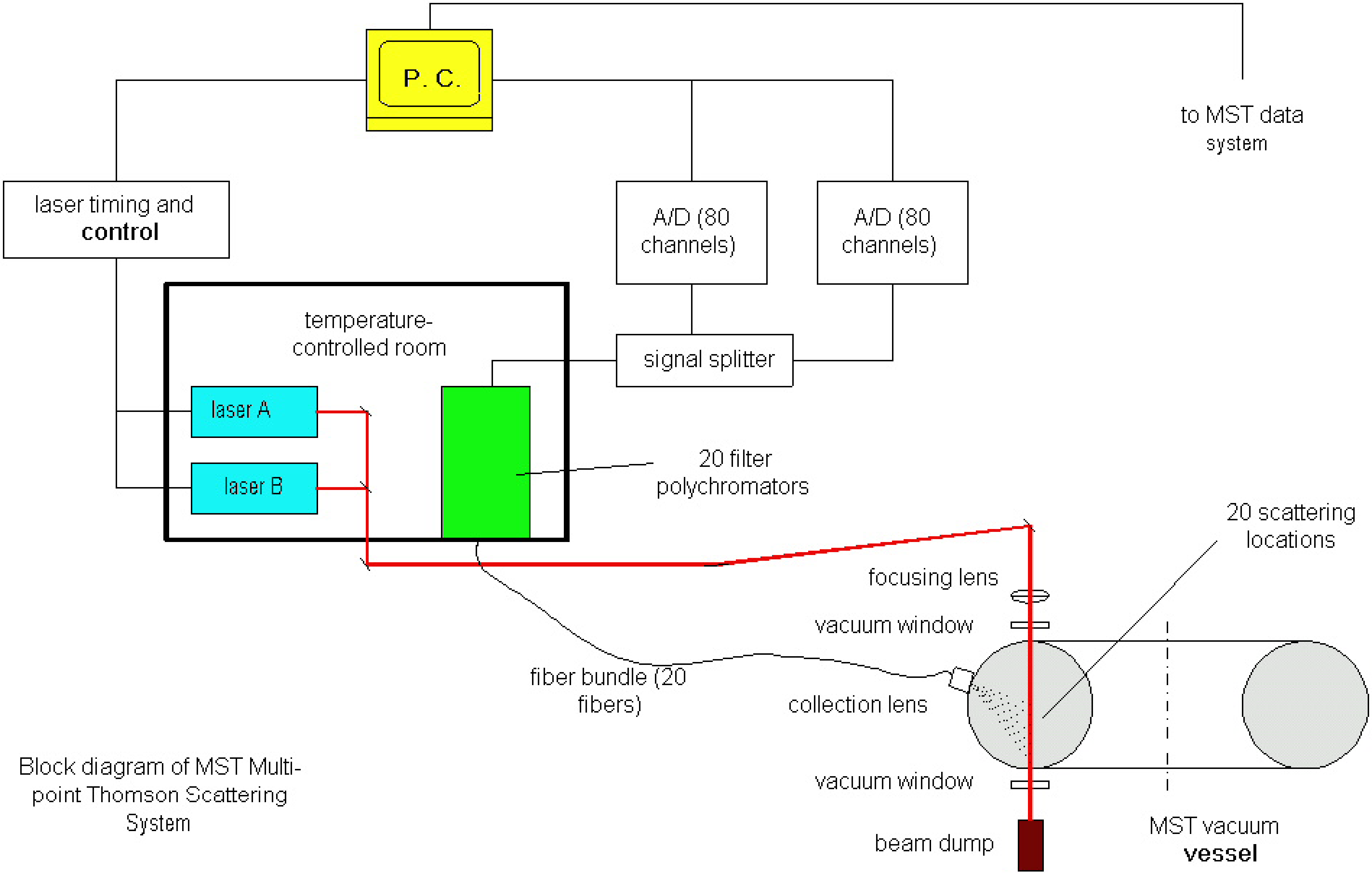
- Plasma current: 500 kA
- Discharge duration: 60 msec
- Best confinement times: 5 msec
- Typical $n_e = 10^{19}\, m^{-3}$, highest $T_e = 800$ eV
- R = 1.5m, a = 0.52m
- 50mm thick aluminum wall serves as 1 turn toroidal field coil, stabilizing shell and vacuum vessel

Multi-point Thomson System

- T_e, n_e at 20 radial points (r/a=0 to r/a=??)
- 1 to 7 time points per (70 msec) plasma shot
- T_e measurement error < 10%(??) for 10 eV < T_e < 2 keV, $n_e > 10^{18}$ m^{-3}
- 2 Nd:YAG lasers, 20 filter polychromators
- Single-pass system

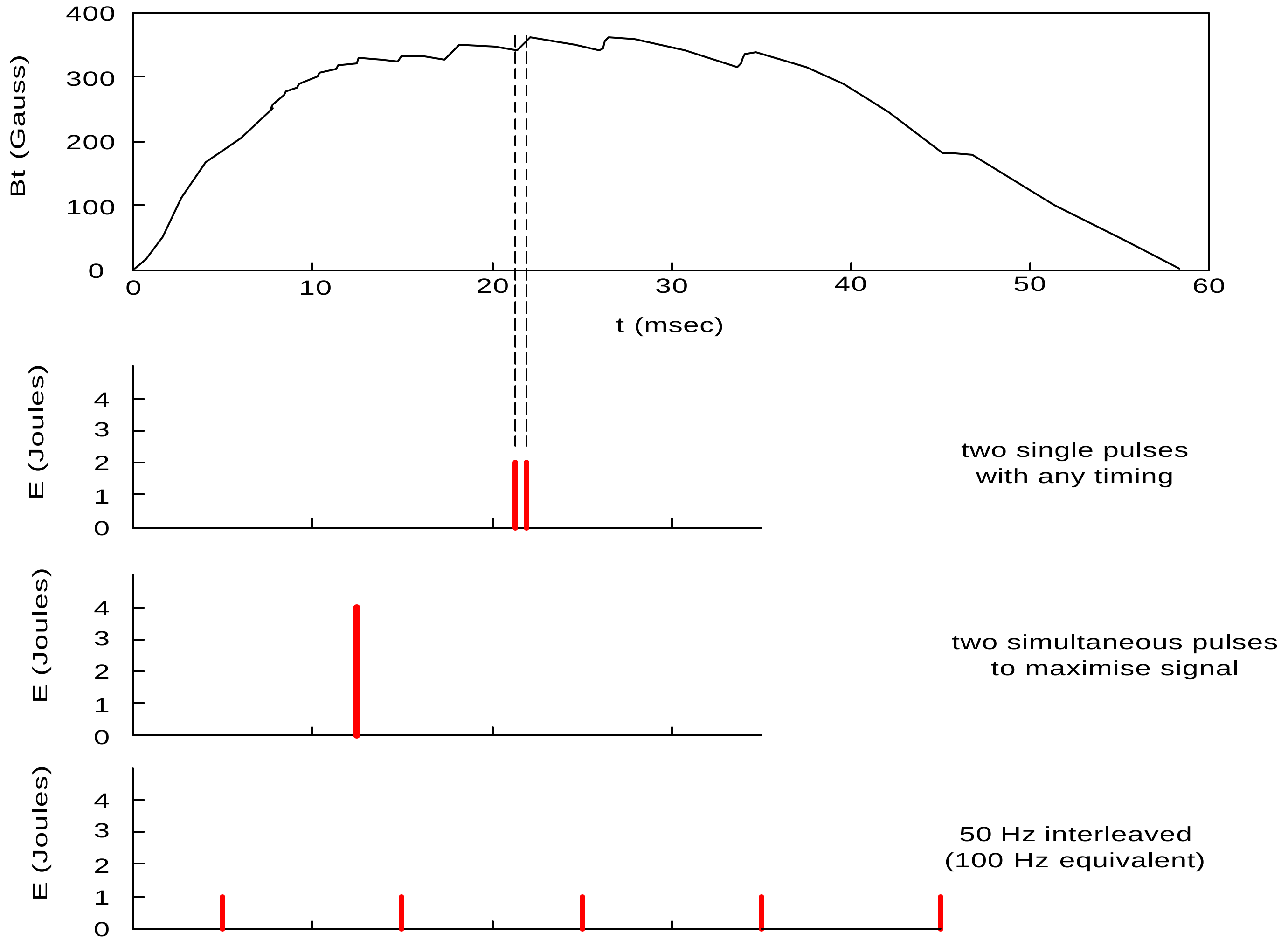
Lasers

- Two identical Flashlamp-pumped, Q-switched Nd:YAG lasers (Spectron)
- Lasers in remote temperature-controlled room
- Single-pulse (2 Joule per laser, 10 nsec pulse, arbitrary timing) to 50 Hz (1 Joule per laser; requires optics swap)



Block diagram of MST Multi-point Thomson Scattering System

Laser timing is flexible:

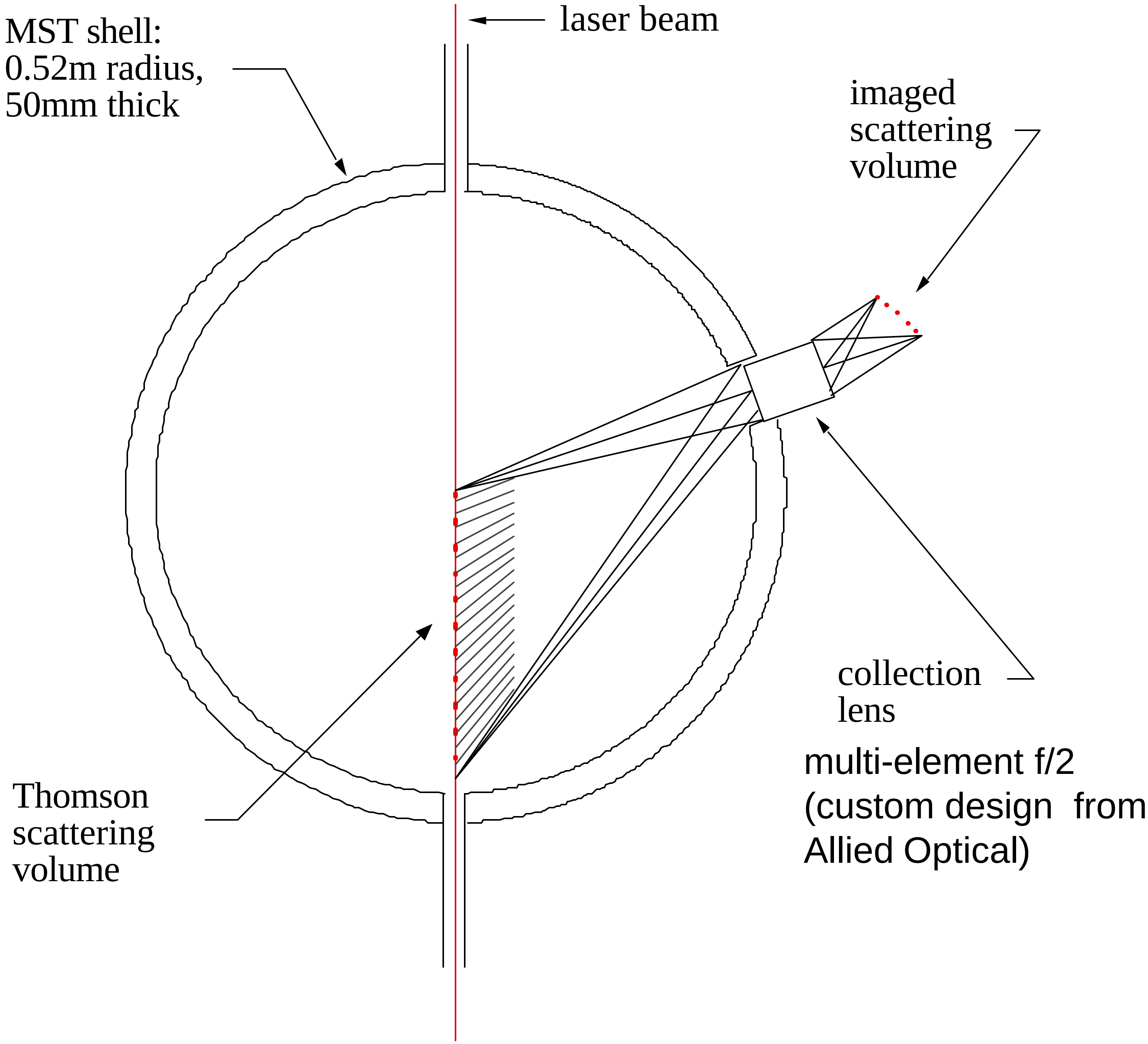


Beam Delivery

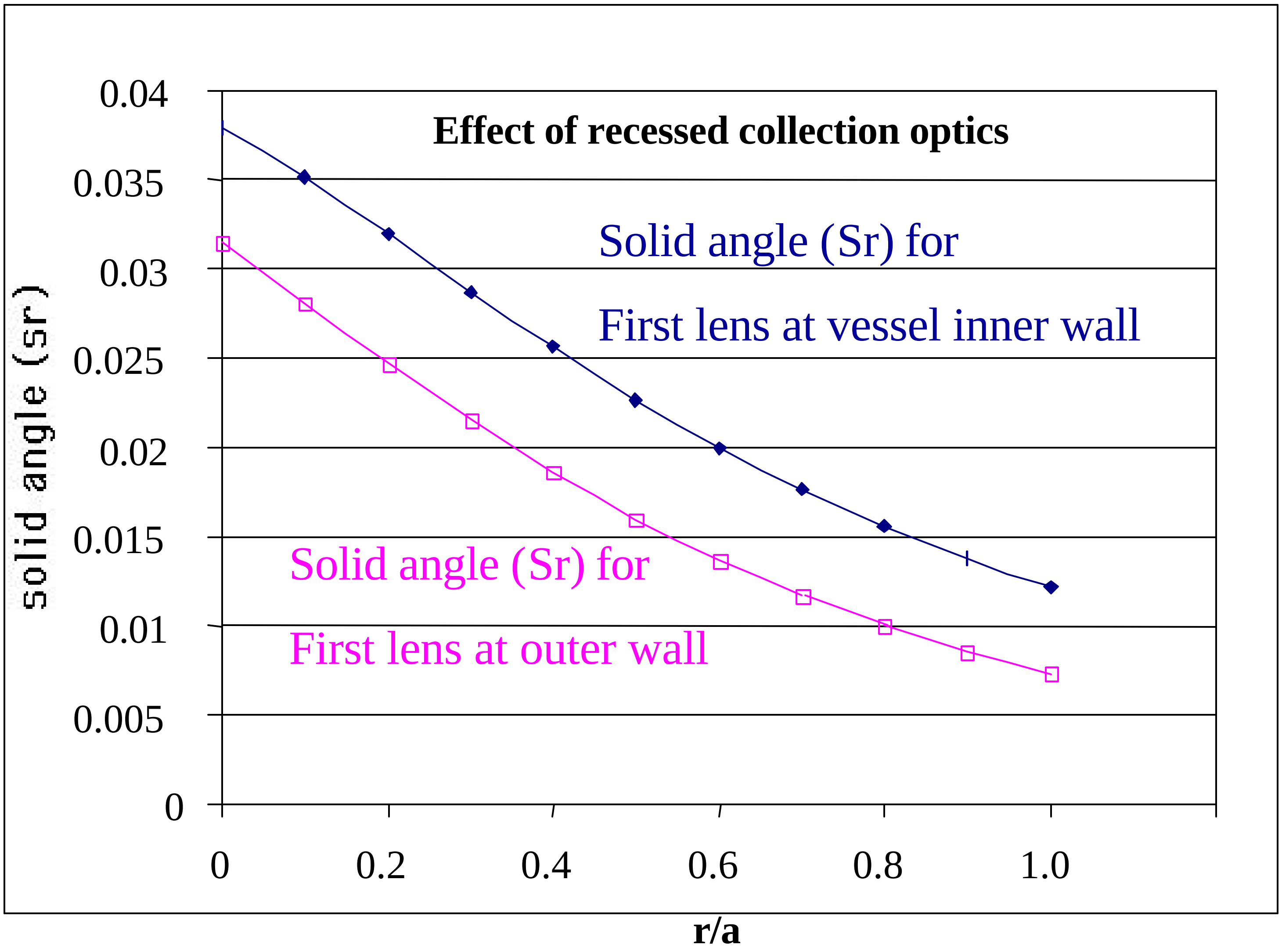
- Single - pass: want back-scattered spectrum
- Two laser beams side by side
- Beam path inside PVC tubes (safety)
- Remote beam monitoring/steering
- Final focus lens, beam dump in air
- Final optics mounted to vacuum vessel (?)

Collection Optics

- Tradeoff between light collection, magnetic field error caused by porthole, plasma damage to first optic
- Damage test result: want distance to plasma > port radius. Active correction of port error field?
- Fiber optics allows remote spectrometer (in temperature-controlled room near lasers)

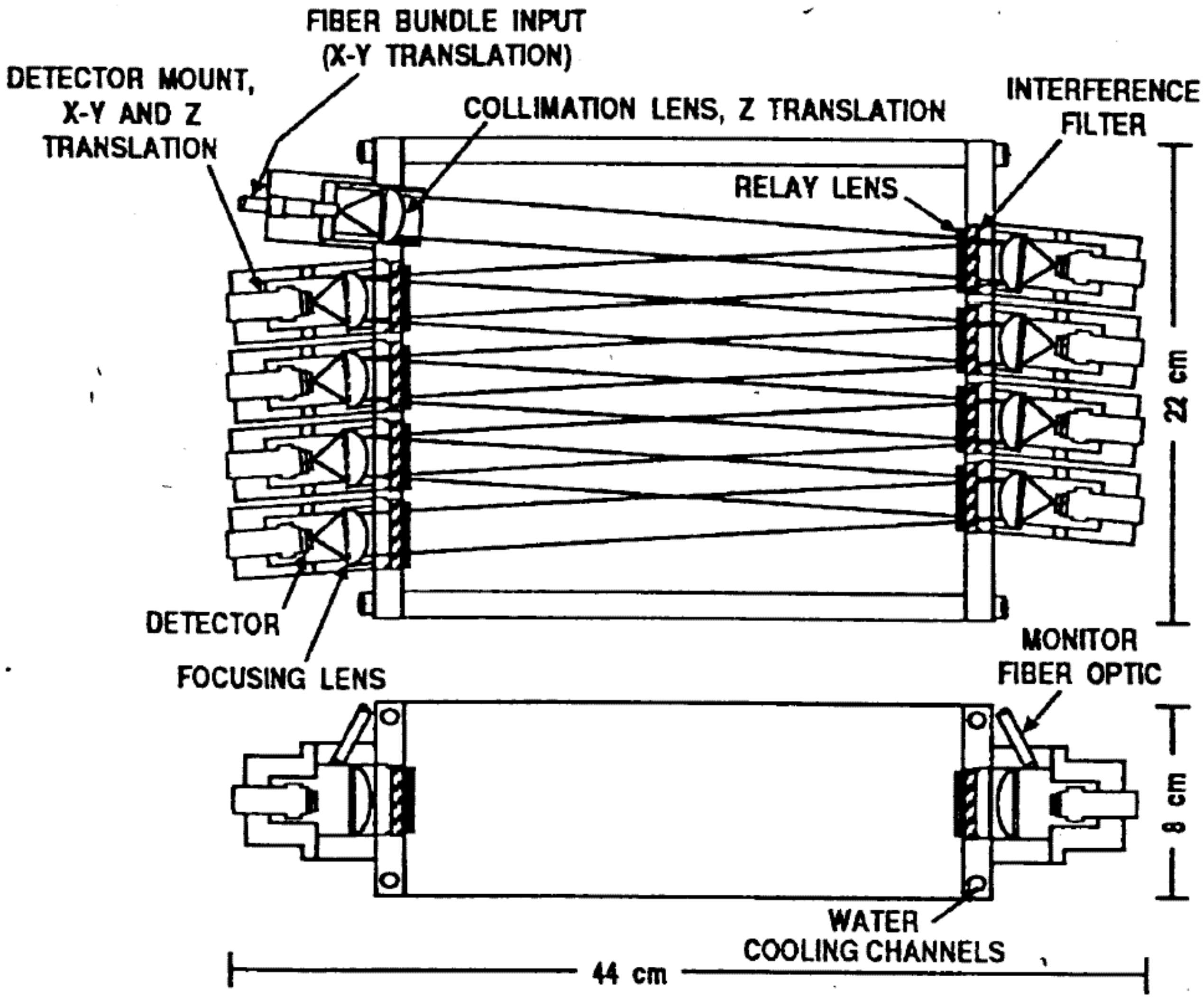

MST shell:
0.52m radius,
50mm thick
laser beam
imaged
scattering
volume
collection
lens
multi-element f/2
(custom design from
Allied Optical)
Thomson
scattering
volume

Light collection from 20 measurement locations varies 3:1



Spectrometers

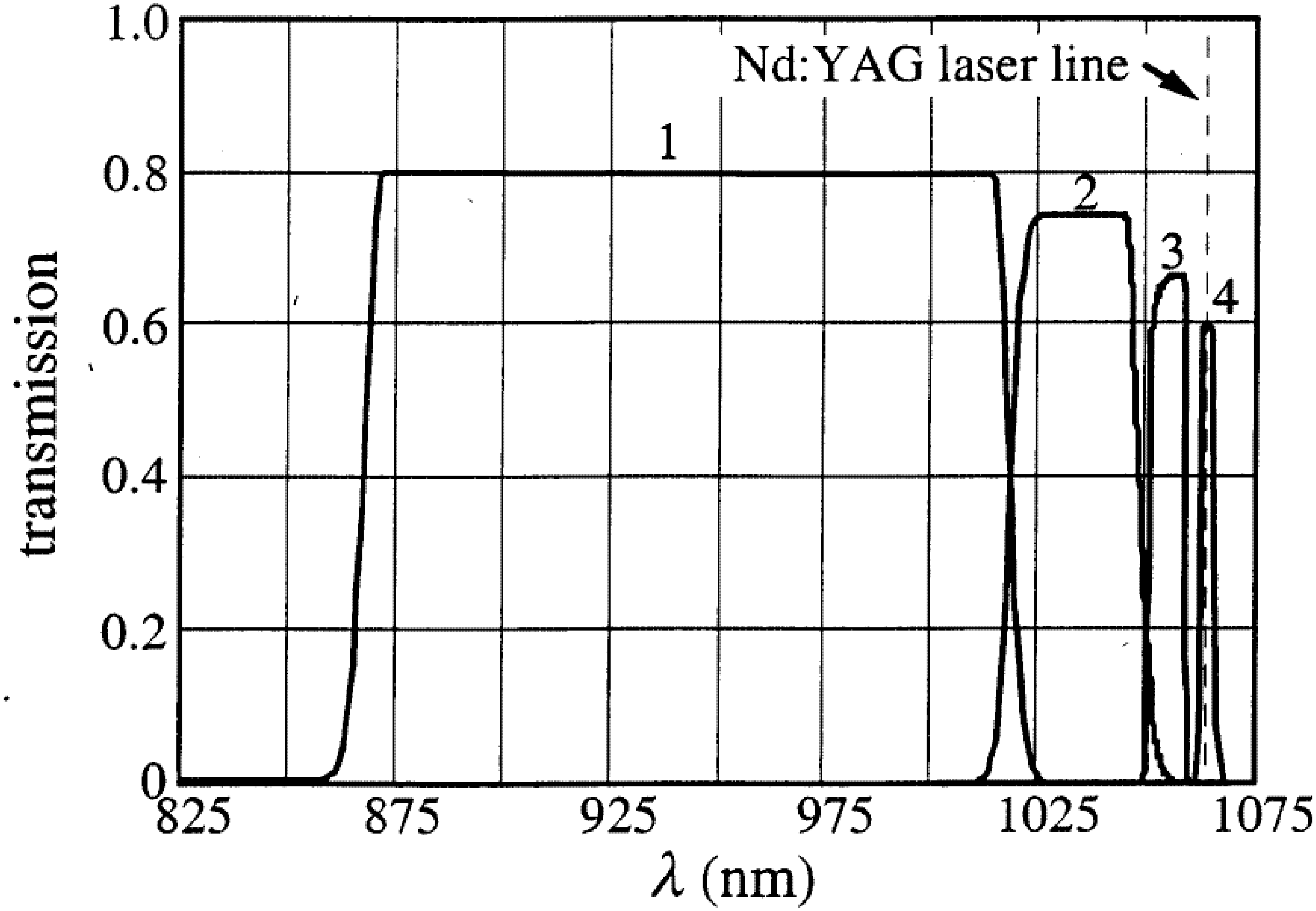
- 20 identical filter polychromators designed and built by General Atomics
- Joint purchase with other experiments to reduce cost
- Light cascaded through series of bandpass interference filters
- Silicon Avalanche Photodiode detectors



SCHEMATIC OF EIGHT CHANNEL POLYCHROMATOR

(Note: we will only use 4 interference filters)

- 3 wavelength channels (+ Nd:YAG line). 4 unused wavelength channels.
- Use few wavelength channels to minimize electronic noise.
- Must assume a distribution (e.g., a single Gaussian) to infer the electron temperature
- Delay line subtraction of background light



Transmission at 1064.3 nm: $\leq 10^{-5}$
Transmission outside passband: $< 10^{-4}$ from 200 to 1200 nm.
Reflection outside passband: > 0.95 from 600 to 1070 nm

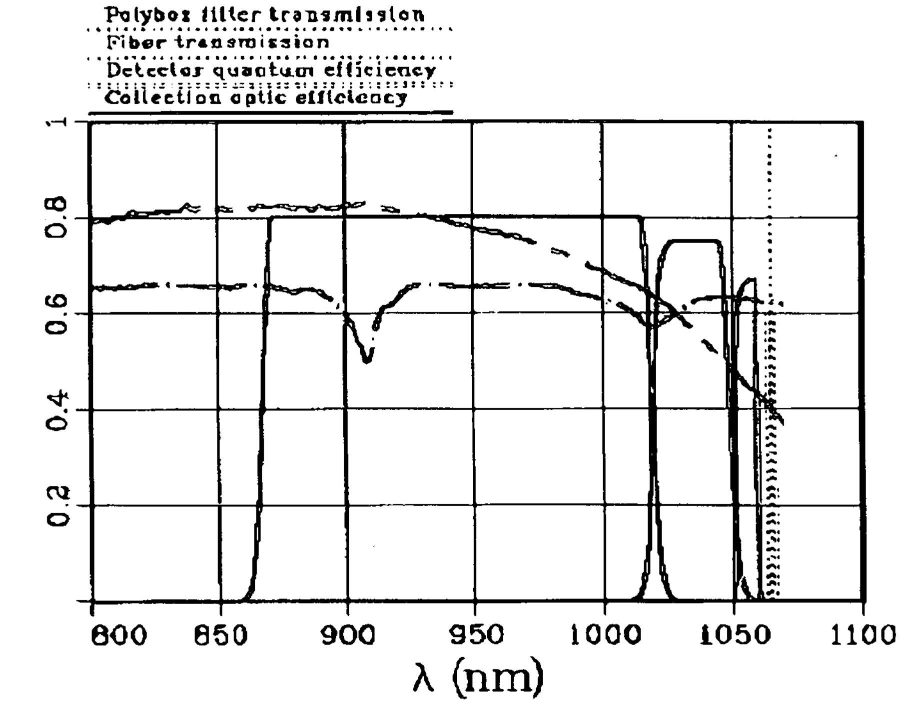
Expected Performance

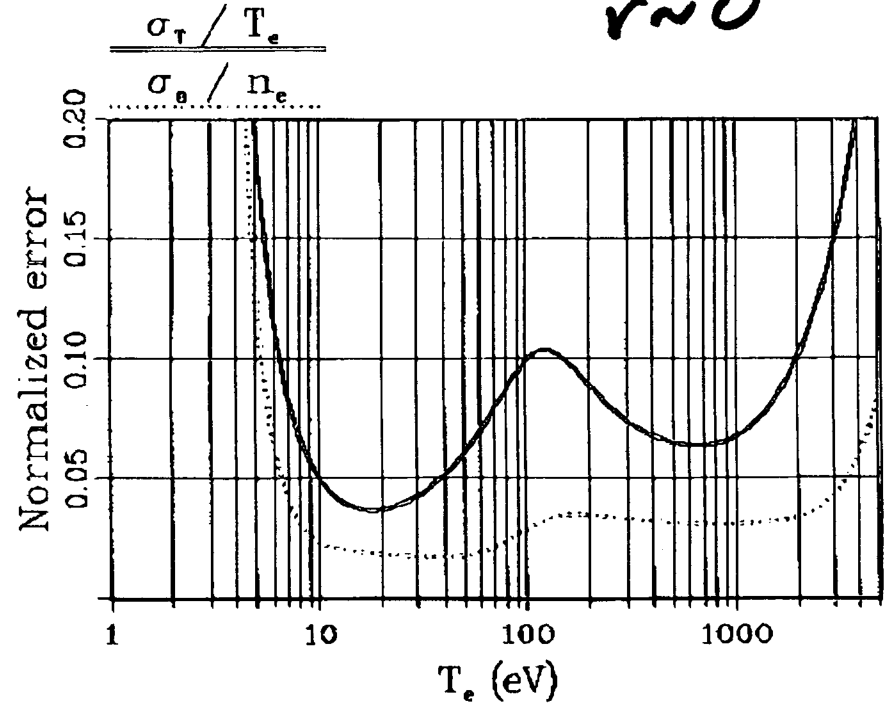
- Central point: T_e uncertainty < 10% from 10 eV < T_e < 2 keV, n_e > 3 x 10 ^{18} m^{-3}
- Edge point: T_e uncertainty < 16% from 10 eV < T_e < 1.5 keV, n_e > 4 x 10 ^{18} m^{-3}

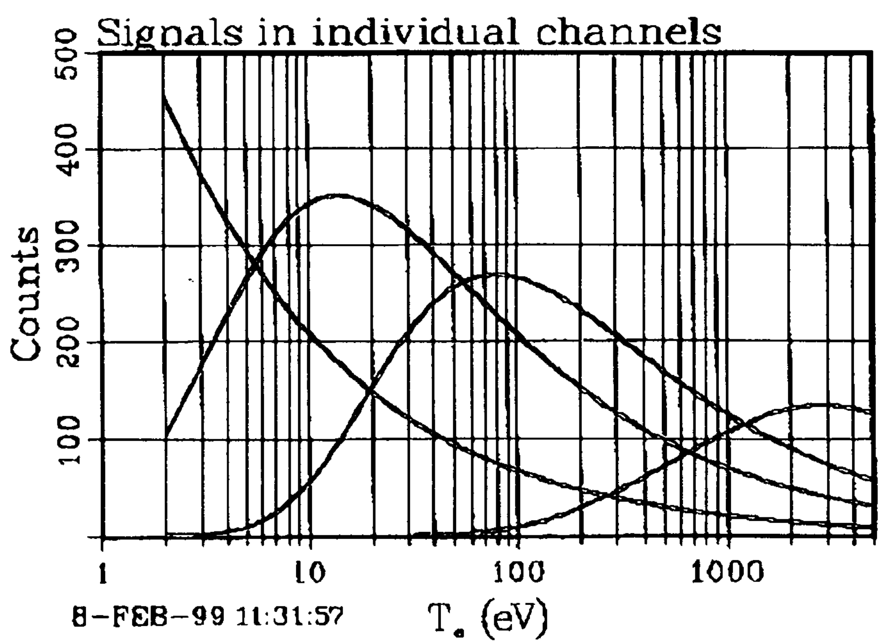
(based on calculations by General Atomics)

MST POLYBOX, 4 CH

Case 2
r~0





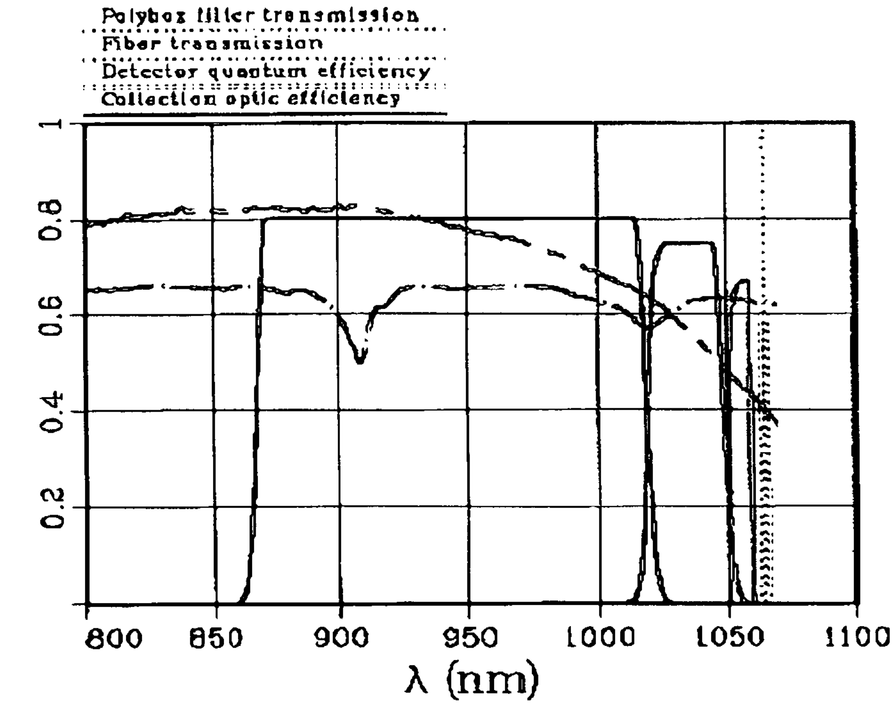


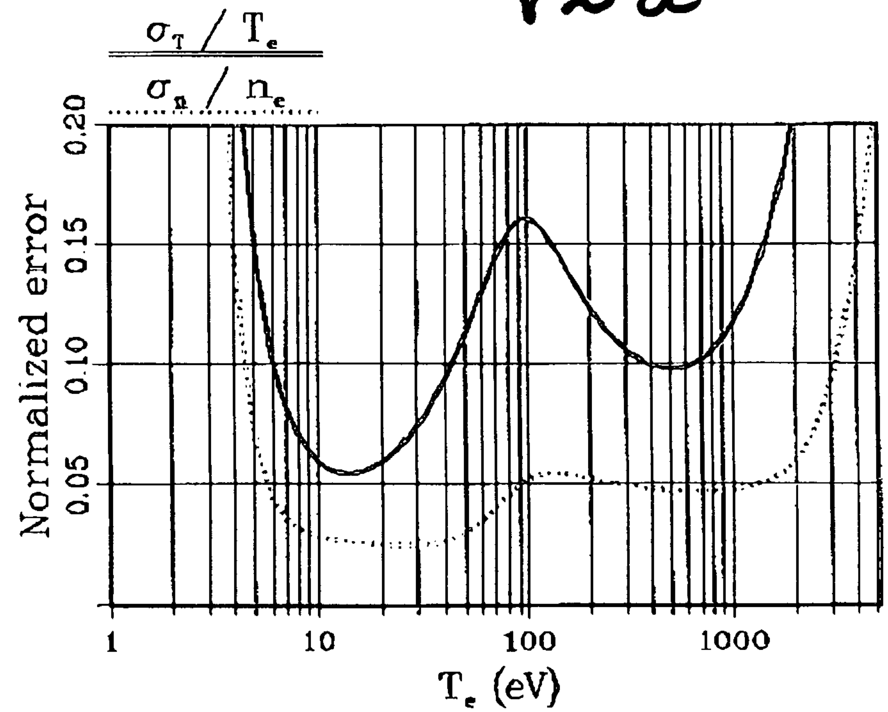
Number of channels = 3
$n/10^{13} cm^{-3}$ = 0.3
θ (degrees) = 109.0
E_{laser} (J) = 1.0
L_{view} (cm) = 1.0
F/no = 4.5
η = 0.9 1.0 1.0
Electronic noise = 140.0
Background light = 20.0
Noise enhancement = 3.0

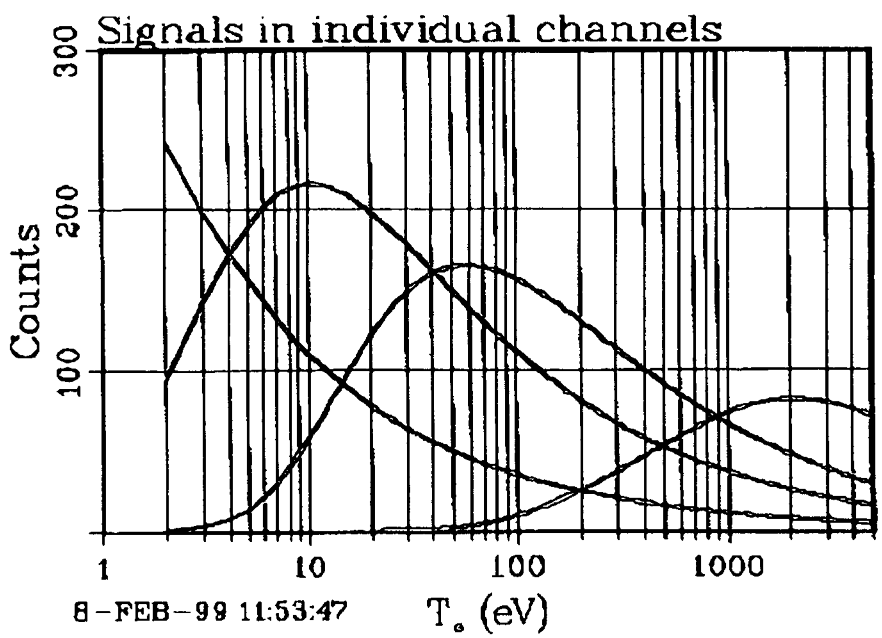
VERSION 3.01 (01/15/99)

MST POLYBOX, 4 CH

Case 7
r~a







Number of channels	=	3
$n/10^{13}cm^{-3}$	=	0.4
θ (degrees)	=	143.0
E_{laser} (J)	=	1.0
L_{view} (cm)	=	2.0
F/no	=	9.4
η	=	0.9 1.0 1.0
Electronic noise	=	140.0
Background light	=	20.0
Noise enhancement	=	3.0

VERSION 3.01 (01/15/99)

Calibration

- Rayleigh scattering from gas at known pressure gives absolute calibration, allows measuring n_e
- Built-in fiber-coupled pulsed LED allows frequent calibration checks

Data Collection and Control

- 80 photodiodes, 160 digitizer channels (allows arbitrary timing of 2 lasers)
- Dedicated PC controls, takes data
- CAMAC digitizers, IEEE 488 to PC
- Serial highway from PC to MST main data system

Summary and Schedule

- 20-point, multi-pulse TS system for MST.
- 2 Nd:YAG lasers, 20 filter polychromators
- Lasers and polychromators expected late 1999. First T_e data expected in late 2000.