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Publication date:
1983

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Gadeberg, M. (1983). The Thomson Scattering System at DANTE. Roskilde: Risø National Laboratory. (Risø-M; No. 2397).

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1

RISØ-M-2397

THE THOMSON SCATTERING SYSTEM AT DANTE

M. Gadeberg

Abstract. This report describes the construction and operation
of the 90 deg Thomson Scattering diagnostic at DANTE. The system
is based on a double-pulse ruby laser and a three channel spec-
trometer. Two single point measurements can be made during each
plasma discharge.

CONTENTS

1. INTRODUCTION

This guide describes the operation of the 90-degree Thomson
Scattering diagnostic at DANTE (Danish Tokamak Experiment).

In its present version this diagnostic comprises a double-pulse
ruby laser, a two-channel spectrometer and the appropriate op-
tics for focusing the laser onto the scattering volume and
imaging this volume on the spectrometer slit. The data acquisi-
tion is computerised. Data is read into the control and analysis
computer (PDP 11/34A) through CAMAC equipment. A set of subrou-
tines called from the MASTER program perform the data reduction
and presents the measured electron temperature and electron den-
sity as results. A schematic layout of the system is shown in
Fig. 1.

The ruby laser and the focusing optics are described in Section
2 together with the appropriate alignment routine. Section 3
describes _he spectrometer and the imaging of the scattering
volume on the spectrometer slit. The dataacquisition system is
the subject of Section 4, and Section 5 contains the calibration
procedure for the data acquisition. The available computer sub-
routines for data reduction and control of the CAMAC equipment
are described in Section 6.

A presentation of results obtained with this diagnostic is given
by Gadeberg (1983).
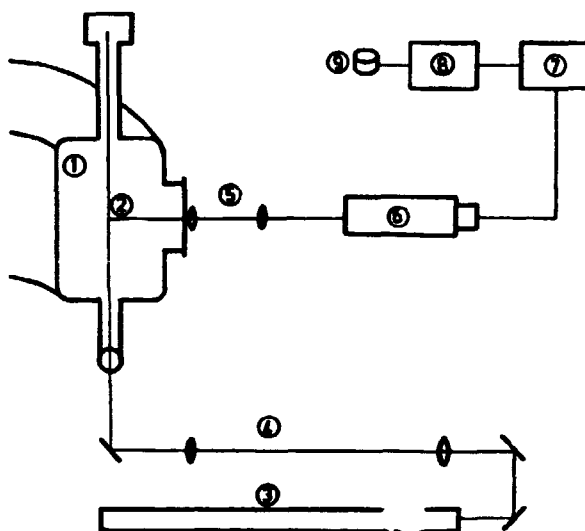
Figure 1. Schematic layout of the Thomson Scattering system at DANTE.

1: Vacuum chamber   2: Scattering volume   3: Ruby laser
4: Input optics   5: Collecting optics   6: Spectrometer
with detectors   7: Data acquisition equipment   8: Computer   9: Data storage

2. RUBY LASER AND INPUT OPTICS

This section describes the double-pulse ruby laser and the input (focusing) optics of the Thomson scattering system. A layout of the ruby laser and input optics is given in Fig. 2.

Subsection 1 deals with the ruby laser in itself, and in subsection 2 the focusing of the laser on the scattering volume is described together with the alignment of the ruby laser with the tokamak.
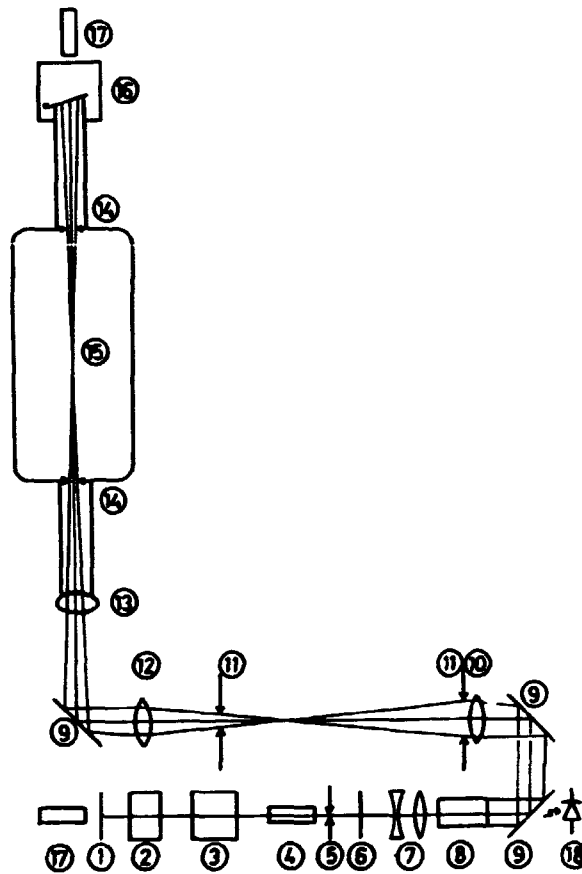
Figure 2. Ruby laser and input optics.

Laser: 1: Laser mirror (100%)   2: Pockels Cell
3: Polarizer   4: Ruby rod, oscillator   5: Aperture
6: Laser mirror (35%)   7: Beam expander   8: Ruby rod,
amplifier.

Input optics: 9: 45deg mirror   10: Lens 1, f=800 mm
Brewster angle   14: Inner aperture   15: Scattering volume
16: Blue glass beam dump   17: He-Ne laser   18: Laser monitor

2.1. Ruby laser

The ruby laser is built around two commercially available laser
heads and a Pockels Cell driver unit from JK Lasers, Rugby,
England. The rest of the laser is designed and constructed at
Risø. All components of the optical part of the laser are shown

in Fig. 2, and the subsequent numbering of items refers to this figure.

For a detailed description of ruby lasers the reader is referred to Koechners book (1976) on solid-state lasers.

2.1.1. Optical parts

Apart from the laser head (4) (ruby rod: 4" × 3(8") the oscillator consists of the Q-switch (Pockels Cell (2) and polarizer (3)), an aperture (5), and the two laser mirrors (1) and (6) with reflectivity approx. 100% and 35%, respectively. The laser amplifier has only one component: the laser head (8) with a ruby rod 8" × 5/8". The oscillator and amplifier are connected through the beam expander (7). For alignment of the ruby laser a He-Ne laser is mounted at the rear end of the laser.

2.1.2. Cooling

The cooling of the laser heads is done in a closed loop filled with distilled water. This loop includes a heat exchanger and circulation pump. A thermoswitch on the heat exchanger operates a valve for controlling the flow of tap water for the secondary side of the heat exchanger. The thermoswitch is adjusted for a temperature of 20 deg C in the closed loop.

2.1.3. Electronics

The flash lamps for pumping the ruby rods are energized by two capacitor banks. Controlling the charging and firing of these banks and of energizing auxilliary equipment is done by two control units (No. 1 for the oscillator and No. 2 for the amplifier).

The cooling switch on the oscillator control unit is used for switching power to the control unit itself, the cooling system, and the power panel at the bottom of the rack. The cooling switch on the amplifier control unit only switches power to this unit. The power keys are used to energize the charging circuits for the capacitor banks.

The charging level of the capacitors is limited by the capacitors to 2800 volts. A three-digit thumb wheel on the front panel sets the charging level. The reading of the dial is not directly related to the charging level. The starting and (pre-)stopping of charging is controlled by two front panel buttons. In order to be able to charge the oscillator the tokamak must be in the charge state. This interlock is to ensure that the door is locked. During maintenance the interlock can be overridden by a switch on the rear panel. A start charge signal is also given by the tokamak control unit when charging the tokamak with diagnostics on. The laser control units respond with a ready signal when the preset charging level is reached.

The firing of the flash lamps is controlled by a front panel trigger on the control unit. Only one trigger lead is needed as the other unit is triggered by the synch pulse of the first unit. The synch pulse of the second unit is used for triggering the Pockels Cell unit. The Pockels Cell unit is set for an internal delay of 1.3 msec before opening the Q-switch. When double pulsing with a separation of 600 microsec and balanced for maximum for pulse 1 the internal delay should be 1.1 msec. The main trigger is derived from the tokamak timing modules.

2.1.4. Internal alignment of ruby laser

Alignment of the oscillator is obtained the following way:

1) Tracking He-Ne beam. Direct the He-Ne beam along the center of the ruby rods. These rods are fixed to the laser bench and cannot be adjusted.

2) Q-switch. For alignment of the Q-switch a diffuser for the He-Ne beam and an extra polarizer is needed. The position of the polarizer on the bench is not adjustable, but it should be roughly centred on the He-Ne beam to transmit horizontally polarized light. The Pockels Cell should also be centred on the laser beam, and when placed between crossed polarizers with a slightly diffused beam, the cross-shaped pattern in the transmitted light should be symmetric about the central spot. (For information on the characteristics of Pockels cells see Adams, 1968)

3) Rear mirror (100%). The mirror must be carefully adjusted so that the front surface is perpendicular to the He-Ne beam.

4) Front mirror (35%). With an autocollimator the front surface of this mirror is carefully adjusted to be parallel to the back mirror surface. The Q-switch must be open during this adjustment. It should be possible to see through both the Q-switch and the ruby rod. If this is not so, the ruby rod can be moved out of the beam. Only the two mirror surfaces should be parallel in order to avoid lasing on other reflections.

5) Aperture. The aperture should now be centred about the He-Ne beam. The function of the aperture is to stop the outer and less intense part of the laser beam, thereby enabling a larger expansion of the beam into the laser amplifier to reduce the beam divergence.

After alignment of the oscillator the lasing should be tested. The output of the oscillator is presently approximately 250 mJ. The tracking of the He-Ne beam should also be checked, and eventually fine adjustments could be made.

The coupling of the amplifier to the oscillator is done through the beam expander. As the amplifier is fixed to the laser bench and the beam expander alone is adjustable, this adjustment must be made to direct the laser beam through the center of the amplifier rod. The expansion ratio is fixed by the choice of lenses, but a focusing effect in the ruby rods can be accounted for by a fine adjustment of the distance between the lenses. This distance should be adjusted so that the ruby beam out of the amplifier is parallel. The adjustment can be made either by measuring the beam width over a significant distance by firing the laser on burn-paper or by focusing the beam with a lens of known focal length. The latter method is preferred, for in the actual set-up this focus is imaged onto the scattering volume. The tracking He-Ne beam should coincide with the focus of the ruby laser.

2.2. Input optics

The ruby laser is placed just above the floor of the laboratory
and underneath the tokamak shooting radially away from the vacuum
chamber. The beam is bent 180 deg by reflection on two 45 deg
incidence laser mirrors (9). Because of possible damage to the
mirrors the laser pulse energy is presently reduced to approxi-
mately 1.2 J. At this power level no damage to the mirrors has
been observed. At higher power levels, damage has been observed,
but the reason for this unexpectedly low threshold is unknown.
A reason might be that in the present set-up the mirrors are for
s-polarized reflections, but they should be for p-polarization
as the ruby laser is horizontally polarized.

Behind the first of the mirrors a fast light-detecting diode
(18) is mounted to measure the transmitted laser light. The sig-
nal from this diode is used for synchronizing the data-acqui-
sition system with the laser pulse and for measuring the laser
pulse energy. A diagram of the monitor is given in Fig. 3. To
get a reasonable signal level a transparent diffuser and some
transmission filters are placed in front of the diode.
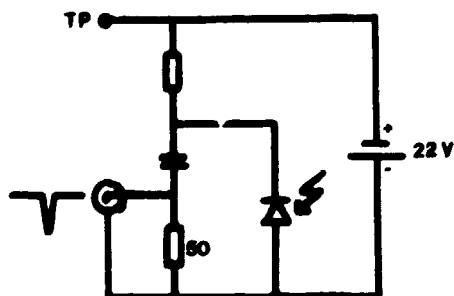
Figure 3. Diagram of laser energy monitor

A lens (10) of focal length 800 mm is placed just after the sec-
ond mirror. This lens focuses the ruby beam to a spot approxi-
mately 1.2 mm in diameter. The focal point is imaged by a second
lens (12) (focal length 400 mm) onto the scattering volume (15)

with an imaging ratio of 1.0. A third mirror (9) is placed
underneath the tokamak to direct the beam vertically up through
the vacuum chamber. The polarization of the vertical ruby beam
is tangentially to the major radius of the vacuum chamber. The
beam enters the chamber through a window (13) at the end of a
tube. In order to reduce reflections in the window this is placed
in the Brewster angle. On the other side of the scattering volume
the beam is dumped in blue glass (16) at the end of another tube.
Also the blue glass is placed in the Brewster angle. To be able
to use the He-Ne laser (17) on top of the beam dump for alignment
the blue glass can be turned out of the beam.

In the tubes to the window and beam dump, a few baffles are
placed. These baffles prevent most of the stray ruby light scat-
tered in the Brewster window from entering the main chamber. The
main baffles (14) are the two at the ends closest to the scat-
tering volume. These baffles are imaged by the second lens (12)
on two apertures (11) between the two lenses, as indicated in
Fig. 2. As the apertures are smaller than the corresponding
images the ruby beam is "cleaned" by the apertures and does not
touch the baffles. In this way the amount of stray light scat-
tered from the baffles is reduced.

2.2.1. Alignment of input optics

Alignment of the ruby laser to the vacuum chamber through the
input optics is obtained as indicated below.

1. Alignment of baffles and apertures. A broad beam of white
   light is shone down through the tokamak in the opposite
   direction of the ruby beam. The beam must be wide enough to
   illuminate the baffle system. The mirror under the tokamak
   and the second aperture is adjusted so that the apertures
   are centred in the bright images of the baffles, while at
   the same time the central part of the mirror is used. This
   usually requires room lights to be off.
2. He-Ne alignment beam through the tokamak. The He-Ne laser
   on top of the beam dump is adjusted so that the beam is
   centred on the apertures. This way the beam will also be
   centred on the baffle system.

3. Making the two He-Ne lasers colinear. The He-Ne laser on
   the ruby laser now tracks the ruby beam, and the other
   alignment laser on top of the vacuum chamber tracks what
   should be the path of the ruby beam through the vacuum
   chamber. When these He-Ne beams are colinear the two sub-
   systems are coupled correctly. The beams are colinear when
   they coincide at two separate points. These points are
   usually defined by two pinholes placed in the centers of the
   aperture (5) of the laser oscillator and of the aperture (11)
   closest to the third 90 deg reflection mirror. At this point
   in the alignment procedure the He-Ne lasers should pass one
   pinhole each. In a dark room it is now possible to see the
   bright spots from the "opposite" laser in the surroundings
   of the pinholes. By adjusting the two mirrors in the 180 deg
   bend, the spots should be made to coincide with the pinholes.
   Note that at the same time the beams must also be centred on
   the mirrors. After removing the two pinholes the ruby laser
   and input system are now ready for operation.

Note

Remember to position the blue glass in the beam dump before
firing the ruby laser.

3. LIGHT COLLECTING OPTICS AND SPECTROMETER

The Thomson scattered light together with some plasma light and
stray ruby light are collected by the collecting optics which
images the scattering volume on the input slit of the spectro-
meter. The spectrometer disperses the light in order to make
measurements of the spectrum of the scattered light. A layout
of the system is given in Fig. 4. The numbering of items in this
section refers to this figure.

In subsection 1 the collecting optics is described and subsection 2 deals with the spectrometer.
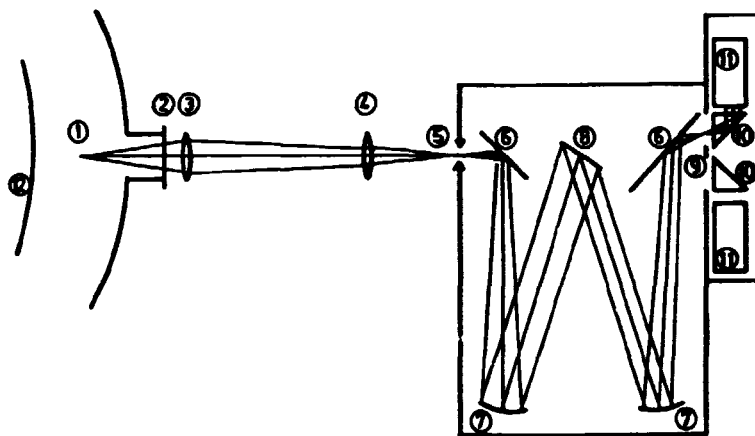
Figure 4. Collecting optics and spectrometer.
Collecting optics: 1: Scattering volume   2: Vacuum window
3: Lens 1, f=200 mm   4: Lens 2, f=320 mm   12: Viewing dump
Spectrometer: 5: Input slit   6: Plane mirror   7: Spherical
mirror, f=590 mm   8: Grating   9: Mask   10: Right-angle
prism   11: Photomultiplier.

3.1. Light collecting optics

There are only two components in the light collecting optics.
These are two lenses: (3) f=200 mm, dia=50 mm and (4) f=320 mm,
dia=50 mm. The first is placed just outside the window (2) of
the vacuum chamber, and this lens defines the solid angle of
light collection. The distance to the scattering volume is
nominally 243 mm and this gives a solid angle of 33.3 mrad. This
lens forms an image of the scattering volume 1130 mm from the
lens. The second lens images this image on the input slit (5) of
the spectrometer. The distance between lenses is 534 mm and be-
tween the second lens and the slit, 208 mm. The imaging ratio
from the scattering volume to the image on the slit is 1.62.
Apart from taking part in imaging the scattering volume on the

slit, the second lens (4) also images the first lens on the first spherical mirror (7) of the spectrometer (see below. This ensures that all light collected by the first lens is measured by the detection system.

In order to reduce the amount of stray light scattered from the innermost wall of the vacuum chamber, this is covered by a viewing dump (12) reflecting only approximately 2% of the light. The viewing dump is a matrix of small steel tubes mounted on a black base plate. A similar dump is placed at the top of the chamber around the tube leading to the beam dump.

3.1.1. Alignment of collecting optics

For alignment of the collecting optics a small steel "mirror" is introduced in the ruby beam path at the scattering volume. The He-Ne beam from the laser on top of the vacuum chamber is shone onto the mirror (He-Ne beam must be aligned with ruby beam). The two lenses are adjusted to give an image of the mirror on the slit and an image of the first lens on the first spherical mirror of the spectrometer. When imaging on the slit only the horizontal position of the image is crucial. The vertical position defines the location of the scattering volume along the ruby beam.

3.2. Spectrometer

The spectrometer is built around a plane halographic grating (8) with 1800 lines/mm. Two spherical mirrors (7) with focal length 590 mm take care of the focusing. Two plane mirrors (6) are placed between the input/output slits and the spherical mirrors to bend the beam path. The input slit (5) has width 4 mm and height 10 mm.

The input slit is placed in the focal plane of the first spherical mirror (7) and therefore the reflected light forms a beam of parallel light which falls on the grating. Light of different wavelengths is reflected by the grating as beams of parallel

light in different directions. The second spherical mirror (7)
focuses the part of the spectrum of interest on the output slit.
Just behind the input slit a red transmission filter (KODAK No.
26) is placed. This filter transmits light only with wavelengths
longer than 600 nm. This way the overlay of first- and second-
order spectra is prevented.

For wavelength selection on the output side the grating can be
rotated around a vertical axis through a spindle system. When
set for normal operation the spindle setting is S = 3.00 on the
exterior dial. In this position the linear dispersion is measured
to be 0.586 nm/mm across the output slit.

Actually the output slit is not a narrow slit but merely a wide
hole in the spectrometer box. This is made in this way in order
to be able to insert a mask (9) for selecting the two wavelength
regions of measurement at the focal plane. In the photomultiplier
box, mounted close to the output hole and behind the mask two
right-angled prisms (10) are placed to direct the light coming
through the mask onto the cathodes of the photomultipliers (11).
In the subsequent calibrating measurements, positions on the out-
put side are determined with a transparent ruler with x=0. mm at
the left edge (closest to the spherical mirror) and x=130. mm at
the right side of the hole.

3.2.1. Spectral calibration

The wavelength calibration of the spectrometer is obtained by
visually observing spectral lines on the output side (photomulti-
plier box and mask not mounted).

In an optical set-up equivalent to the input optics a spectral
lamp is placed in the equivalent position of the scattering
volume. To obtain good accuracy in reading the position of the
line on the output side the input slit is masked to a width of
approx. 0.5 mm.

Note

Spectral lamps require several minutes warm-up before the lines
are stable.

Now two separate calibrations are made. In the first the grating
is rotated to position the lines at a fixed point across the out-
put hole (x = 75.0 mm). The wavelengths of the lines are given in
Fig. 5 as a function of the dial reading.

The second calibration is a measurement of the linear dispersion
of the spectrometer. With a fixed grating the positions of the
spectral lines on the output side are measured, and the disper-
sion can be calculated. Figure 6 shows the measured linear dis-
persion as a function of the dial reading.

For the measurements of Figs. 5 and 6, lines from HeI, NeI, and
CsI bulbs have been used.

On this basis the mask for the output side may be designed and
installed. After installation we want a measurement of the actual
wavelength regions passed by the mask. For this purpose the spec-
tral lamp is removed and replaced by a calibrated spectrometer,
where the output slit is in the position of the scattering vol-
ume. The input slit of the second spectrometer is illuminated by
a tungsten lamp. By varying the wavelength setting of the second
spectrometer and measuring the signals from the photomultipliers
the exact wavelength bands can be determined.
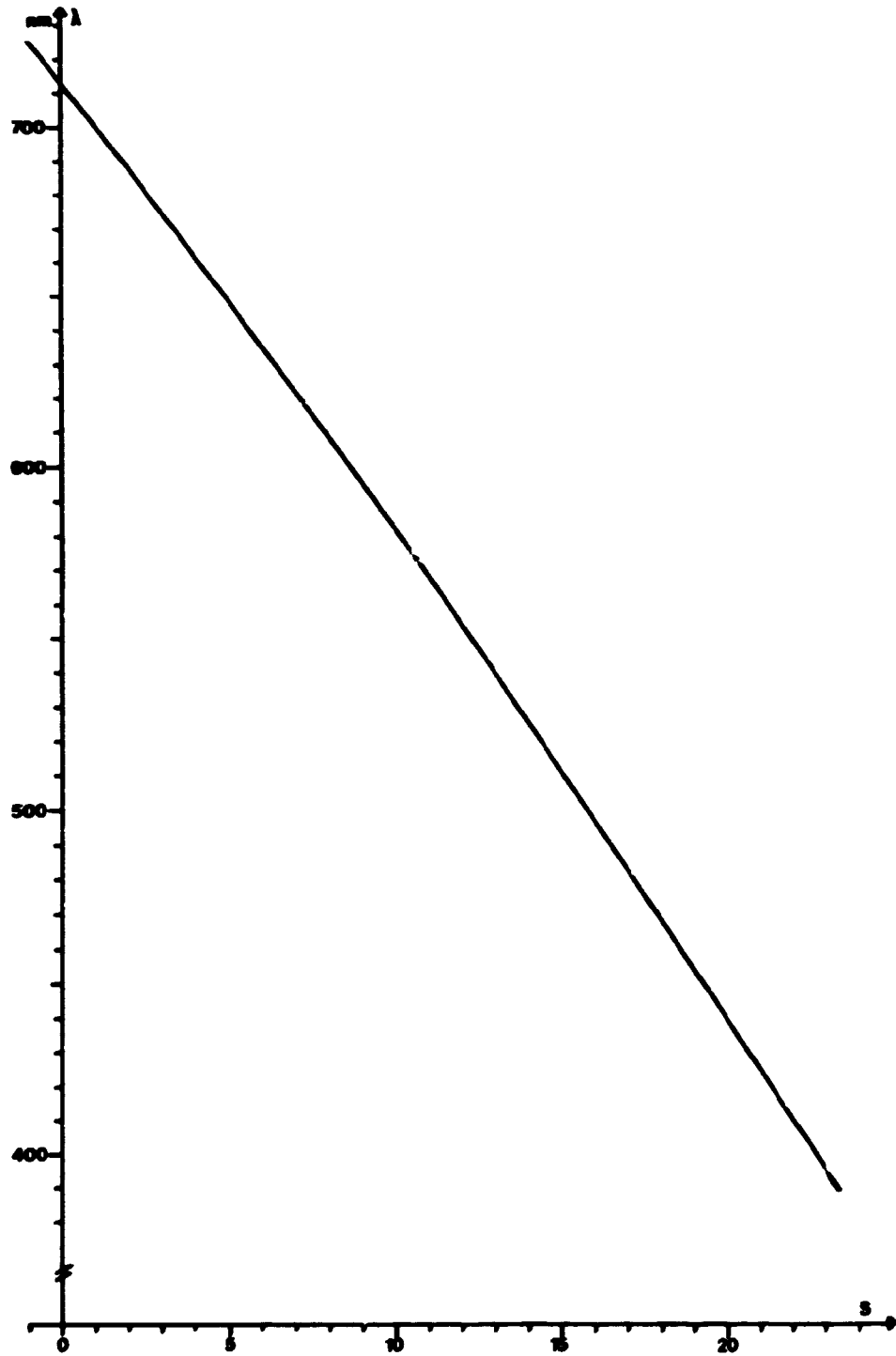
Figure 5. Spectrometer calibration, wavelength.
Wavelength at fixed output slit position (x = 75.0 mm)
as a function of dial reading.
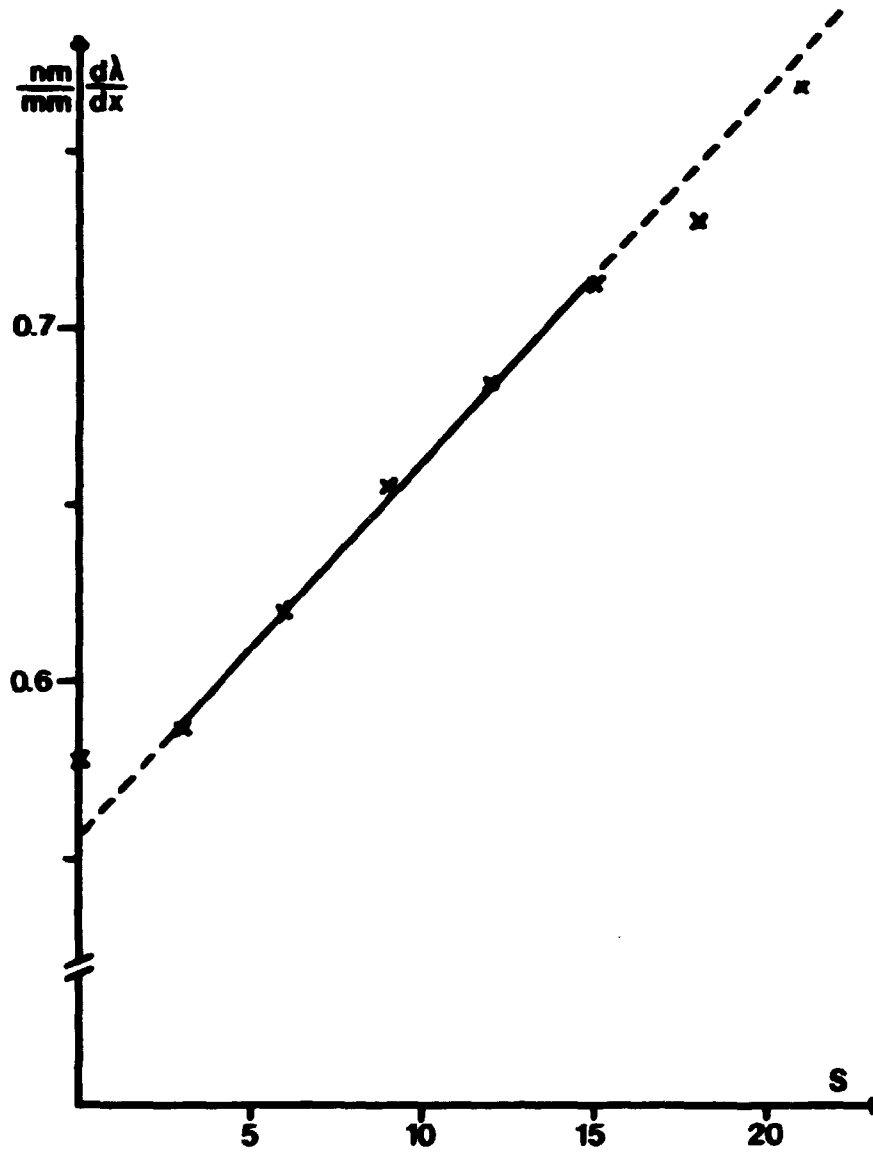
Figure 6. Spectrometer calibration, linear dispersion.
Linear dispersion across output slit for fixed grating as
a function of dial reading.

4. DATA ACQUISITION SYSTEM

This section describes how signals from the photomultipliers are converted to numbers in the computer.

The first subsection gives a description of the photomultipliers, and subsection 2 contains information on the electronics modules mainly in the CAMAC crate.

4.1. Photomultipliers

The photomultipliers are RCA 8852 (S-20 extended red) with a typical quantum efficiency of 5% in the wavelength region of interest. The photomultipliers are mounted in a separate box which is usually attached to the spectrometer.

Note

Care must be taken when mounting the photomultiplier box on the spectrometer to make the connection completely light-tight.

To reduce the influence of the magnetic field fom the tokamak the photomultipliers are placed in envelopes of mumetal.

The photomultipliers are energizeu from a common high voltage power supply usually running at -1900 volts. An interlock ensures that the high voltage can only be on when the spectrometer is closed. The electronics diagram for the tubes is given in Fig. 7. The circuit is similar to the recommended circuit for fast pulse response except around the cathode. In order to reduce the gain of the photomultipliers when not measuring, the potential of the cathode is equal to the dynode 1 potential. Through a transformer arrangement the cathode is lifted -600 volts from dynode 1 during measurements. The measurement period is limited by the transformer to approximately 800 microseconds.

Warning

When opening the transformer box remember that the secondary
side is floating at -1300 volts if not disconnected.
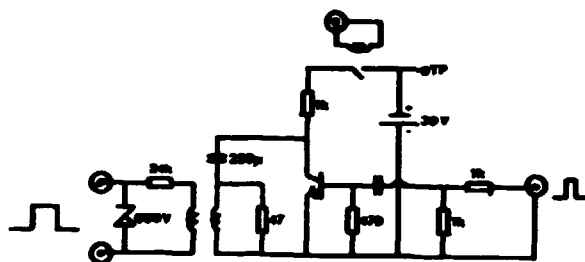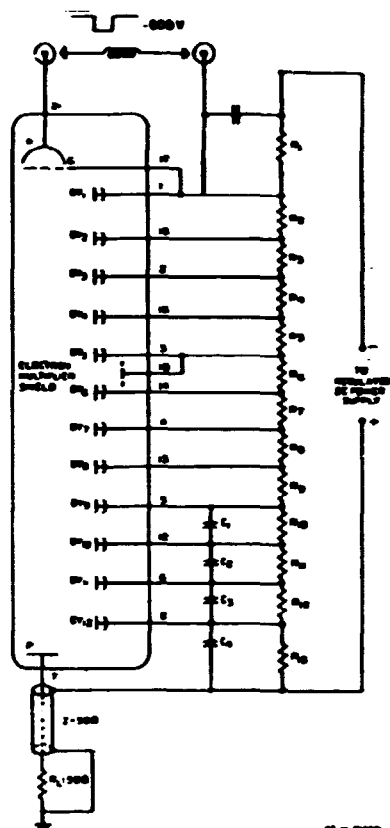
Figure 7. Photomultiplier and gating circuits.
A: Photomultiplier high voltage chain. B: Circuit to
produce gate pulses for photomultiplier.

The gating of the photomultipliers is presently derived from the
Pockels Cell unit of the ruby laser. To give time for stabilizing
the photomultipliers the Pockels cell unit is modified to give a
trigger signal 85 microsec before the first laser pulse. This
trigger then opens the gate for the photomultipliers so that they
are ready when the light pulse arrives.

The primary side of the transformer is energized by a 30-volt
battery. To extend the lifetime of the battery the unit is
switched by a relay from the high-voltage unit. On the front
panel there is also a test point for the 30 volts. A diagram is
shown in Fig. 7.

4.2. Electronics

The anode signal from the photomultipliers is led directly to a
gated integrating ADC (LeCroy 2250L) in the CAMAC crate. In the
ADC the pulses are integrated and stored in a local memory for
readout to the computer at a later time. The ADC has 12 parallel
input channels (all channels measured for each gate), and the
memory can store data for up to 32 gate pulses. The gate pulse
for the ADC is derived from the laser monitor at the front end
of the ruby laser.

The signal from the laser monitor is fed into the Gate Pulse
Trigger module (Risoe P1358) in the CAMAC crate. In a resistive
network the monitor signal is split into an energy monitor signal
for the ADC and a signal for timing the gate pulse for the ADC.
The latter is sent to the Constant Fraction Discriminator (Ortec
463) which in turn delivers a negative trigger pulse to the Gate
Pulse Trigger module. The discriminator level of the Constant
Fraction Discriminator can usually be set at approximately 100
mV. The trigger pulse is inverted in the Gate Pulse Trigger mod-
ule and sent to the Gate Pulse Generator (Culham 95/8293-1/6),
which for each trigger delivers two gate pulses for the ADC.
The timing of the first gate pulse must be adjusted on the Gate
Pulse Generator so that the photomultiplier signals fall within
the gate period. The second gate pulse should appear some micro-
sec after the first pulse. The two gate pulses should have the
same length and be as short as possible but longer than the
signal length. See the manual for a further description of the
Gate Pulse Generator. Note that all signal cables are terminated
in 50 ohms.

The Constant Fraction Discriminator also gives a positive monitor signal which is added to the plasma current signal and used to indicate the time of measurement. The module has been modified to extent the length of the monitor pulse.
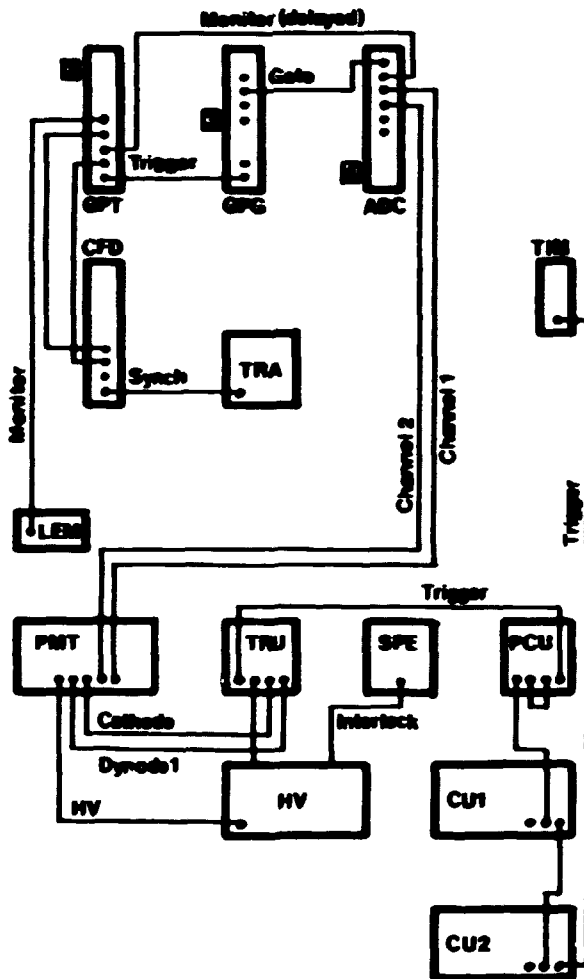
Figure 8. Electrical connection of the modules of the diagnostic.

ADC: LeCroy 2250L ADC, CFD: Constant Fraction Discriminator, CU1 and CU2: Laser control unit 1 and 2, GPG: Gate Pulse Generator, GPT: Gate Pulse Trigger, HV: High Voltage Unit LEM: Laser Energy Monitor, PCU: Pockels Cell Unit, PMT: Photomultiplier Unit, SPE: Spectrometer TIM: Central Timer, TRA: Transient Recorder, TRU: Transformer Unit.

Number in square indicate CAMAC station number.

Of the two gate pulses for the ADC the first is used for measuring scattered light and the second for measuring background

plasma light some microseconds afterwards. The laser energy moni-
tor signal from the Gate Pulse Trigger module must be delayed in
a delay cable to reach the ADC at the same time as the signals
from the photomultipliers.

Figure 8 gives a layout of the electrical connections of the
diagnostic.

5. CALIBRATION OF DATA ACQUISITION SYSTEM

The calibration of the data acquisition system includes a
measurement of the amplification of the photomultipliers. This
automatically gives the amount of electrical charge per detected
photon. Then, of course, the ADC conversion must be calibrated
to give the relation between reading and input charge for each
channel.

Next we make an absolute calibration of the detection system.
By using the sensitivity of the photomultipliers as found above,
this readily gives the product of the transmission of the opti-
cal system and the photomultiplier quantum efficiency. For plasma
temperature measurements only the ratio between the transmission
of the two channels enters the calculations, but for density
measurements the absolute values are essential.

The measurement of Thomson scattered light includes some stray
ruby light. To obtain the true amount Thomson scattered light
the stray light level must be subtracted. This is the reason for
a stray light calibration.

Finally, we need to calibrate the ruby laser energy monitor. This
is used only for calculating the plasma density and for monitor-
ing laser performance. The plasma temperature is calculated from
the ratio of the number of scattered photons in the two wave-
length regions.

Subsection 1 describes the calibration of the ADC module, and the following subsection shows how to calibrate the photomultipliers. The measurement of the optical transmission and the absolute calibration is given in subsection 3. Subsection 4 deals with the energy monitor calibration and finally, subsection 5 describes the stray light calibration.

5.1. Calibration of integrating ADC (LeCroy 2250L)

The calibration of the integrating ADC is a measurement of the pedestral and conversion factor for each channel of the module.

The module can be calibrated in two ways: The first uses the procedure employing the inhibit signal and self-generated gate pulse as described in the manual for the module. The reader is referred to the LeCroy manual for further description. A computer program (THOM4.FOR) which uses this method is available.

The second procedure which has become possible after the delivery of the Gate Pulse Trigger module is equivalent to the first, except that the gate pulse is started softwarewise in the Gate Pulse Generator and subsequently the ADC in the usual way. This way we can avoid using the CAMAC inhibit signal. An advantage of this method is that the gate pulses are generated in the same way as when measurements are made. This procedure has not been employed yet, and no computer program is presently available, though the THOM4.FOR program will require only slight changes to function with this method. Note that now two gate pulses are generated for each CAMAC command.

5.2. Measurement of photomultiplier amplification

The measurement of photomultiplier amplification is done by observing the signals from single photons on an oscilloscope. The light level on the cathode is kept so low that single photon events can easily be distinguished. By measuring the pulse height and width the detected charge can be calculated. The amplification is then found by dividing by the electron charge.

With high voltage on 1900 volts the sensitivity has been measured
to 0.63 and 0.47 pC per photoelectron for channels 1 and 2, re-
spectively (Amplification: 3.9E6 and 2.9E6). The amplification
increases drastically with the high-voltage level (like V**9.8
from 1200 to 2200 volts), but as the sensitivity of the ADC is
nominally 0.5 pC per count 1900 volts is a reasonable voltage
level.

A large sample of data is necessary for this calibration as the
spread in pulse hight is relatively large. Remember to terminate
the signals in 50 ohms on the oscilloscope - You don't want to
repeat the measurements! The above results were obtained from
200 events each.

5.3. Absolute calibration of sensitivity

Measurements of the transmission of the optical system including
photomultiplier quantum efficiency are made by shining white
light from a calibrated tungsten lamp onto a white, uniformly
diffusing reflector inserted in the optical set-up.

A plate covered with fresh magnesium oxide is a standard reflec-
tor for uniform scattering over a half sphere. (The reflector
is made by depositing smoke from burning magnesium on the plate).
Such a reflector is placed just after the first lens of the col-
lecting optics ((3) on Fig. 4) and facing the spectrometer. (A
test has shown that other reflectors not so vulnerable as mag-
nesium oxide might be used, e.g. the inside surface of a Polaroid
film packing). For illuminating the reflector a calibrated tung-
sten lamp radiating at approximately 2900 K is used.

Note

Tungsten lamps require approximately 15 minutes to stabilize the
radiation level.

The signals from the photomultipliers are observed on an oscillo-
scope, and by varying the distance from the lamp to the reflector
and the temperature of the lamp a reasonable signal level is
found. Unfortunately, the signals are rather noisy, so a direct
reading by the ADC is not convenient. Instead, we make use of a
fast RC-filter and take the readings from the oscilloscope. By
applying the above calibration factors for charge per photoelec-
tron the intensity of detected photoelectrons (photoelectrons/
sec) can be calculated. Intensities of 5.7E8 and 2.0E9 photo-
electrons/sec for channel 1 and 2, respectively, have been used
at 1900 volts without observing saturation effects.

The number of reflected photons per srad at any wavelength can
be calculated from the Planck formula, from the knowledge of the
areas of the tungsten band and the reflector and the distance
between them. Here the area of the reflector is set equal to the
area of the first lens. By numerical integration the number of
reflected photons for each channel can be found. Data corespond-
ing to the above intensities gave 2.7E14 and 7.8E14 photons/sec/
srad, respectively. The solid angle mentioned here is a measure
of the cone of detected light from the reflector. As we want to
calculate from the scattering volume, we multiply these figures
by the ratio between the areas of the scattering volume (actu-
ally the image of the slit) and the reflector. Dividing by the
photoelectron intensities we find that each detected photo-
electron corresponds to 3700 and 3000 photon/srad emitted by a
source at the scattering volume for channel 1 and 2, respect-
ively. Taking into account the solid angle, the efficiency of
the detection system is found to be of the order of 1%.

This calibration procedure contains two systematic errors. The
most important error is the neglect of the transmission of the
vacuum window and the first lens. Taking the transmission to be
flat over the wavelengths of interest, this does not influence
the temperature measurements, but leads to a misjudgement of the
plasma density of roughly -10%. The second error comes from the
fact that the first lens of the collecting optics is the aper-
ture limit when viewing the scattering volume. This limit is not
included in the calibration, and when putting the area of the

reflector equal to the area of the first lens an error is made. Fortunately, the new aperture limit is set by the grating, where under normal circumstances the image of the first lens covers 97% of the surface. The error introduced this way is therefore hardly noteworthy.

5.4. Laser energy monitor calibration

The calibration of the laser energy monitor ((18) on Fig. 2) is done simply by correlating the computer readout with readings of an already calibrated laser energy meter. Usually energy meters of the volume-absorbing type is used. When inserting the meter head in the beam path care must be taken, that the beam is fairly distributed on the surface (i.e. avoid a focus).

The energy monitor reading is usually correlated with the beam energy after the first lens in the input optics. This means that losses between this position and the scattering volume are not measured. What is interesting from a diagnostic point of view is the laser energy at the scattering volume, but this is not easily measured.

5.5. Stray light calibration

Measurements of the level of stray ruby light can be made between the usual plasma temperature and density measurements. The data analysis routine tests for plasma on the data-set, and if there is no plasma the Thomson scattering data are considered a measurement of stray light. The level of stray light is considered proportional to the ruby laser pulse energy, and stray light data are normalized to a laser energy of 1 joule. So, to make a stray light calibration fire the Thomson scattering diagnostic in the usual way but without plasma. The data handling routines (Section 6.2.2) will take care of the rest.

6. DATA ANALYSIS AND COMPUTER PROGRAMS

This section describes how the temperature and density of the plasma is calculated from the measured signals, and it gives a description of the available supporting routines on the computer. Computer programs and subroutines are listed in the appendices.

6.1. Basics of data analysis

For a low-temperature plasma the spectrum of scattered light is Gaussian around the laser wavelength and with a full-width-at-half-maximum of 3.23*SQRT(T) nm (T in eV). For a detailed treatment of the scattering the reader is referred to Sheffield, 1975. The plasma temperature is found from the width of the spectrum, and the density from the amplitude.

In this diagnostic the Gaussian spectrum is determined from the ratio of the signals integrated over two significant parts (channel 1 and 2) of the blue flange. The channels have been placed on the blue side of the laser line because photomultiplier quantum efficiency increases when going to shorter wavelengths. The channels should avoid measuring line radiation from the plasma and laser, so therefore they have been placed between the laser line (694.3 nm) and the Lyman-alpha line for hydrogen (656 nm).

The actual position of the channels has been chosen so that equal signals are expected at a temperature of 100 eV. When calculating the expected signals a typical variation of the quantum efficiency with wavelength has been taken into account. This resulted in a mask for the spectrometer for which the actual channels have been measured to be:

Channel	Lower limit	Upper limit
1	684.6 nm	692.3 nm
2	658.3 nm	682.6 nm

If the expected temperature is no longer 100 eV, a change of the channels mignt be useful, as the accuracy of the measurement is best when the two signals are about equal.

In a measurement the actual number of scattered photons in the two wavelength regions are calculated from the ADC data. The ratio of the number of scattered photons is then compared with a theoretically calculated table giving this ratio as a function of temperature. Figure 9 displays the variation of this ratio of scattered light with plasma temperature. The temperature is found by interpolation in the table. The table also contains the theoretical number of scattered photons at a lasr pulse energy of 1 J and a plasma density of 1.E17 m-3. By normalizing the actual number of photons by the actual laser energy and relating this number to the theoretical number the density can be found.
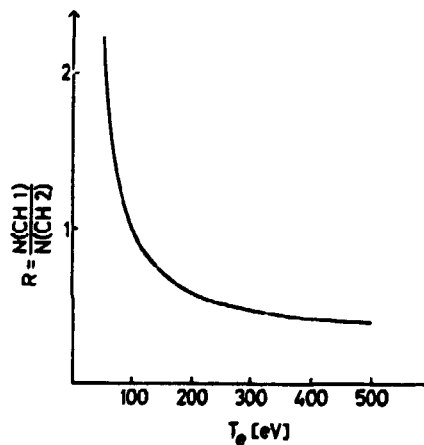
Figure 9. Ratio of scattered light in channels 1 and 2 as a function of plasma temperature.

6.2. Computer programs

A set of computer programs and subroutines are available for data acquisition and reduction and for control of CAMAC equipment.

6.2.1. Data aquisition

Data acquisition is done through the MASTER program, and all raw data are stored shot by shot on data files together with all other data.

In the MASTER program Thomson scattering raw data are stored in the array INTEGER ILAS(6,4) allowing for 6 data channels to be read 4 times per plasma pulse. Presently only 3 of the 6 data channels are in use (laser energy, spectrometer channels 1 and 2). In the second (time) dimension the array contains data for first laser pulse, background for first pulse, second laser pulse and background for second pulse (the last two only if double pulsed).

6.2.1.1. Subroutine ADC12. The subroutine ADC12 is linked to the MASTER program, and it is call twice for each plasma shot. In the first call the subroutine clears and arms the ADC module just before the plasma shot. In the second call data is read out from the module and stored in the array ILAS. A log of the raw data is printed on the terminal. The position of the ADC in the CAMAC crate is taken to be station No. 4 in the subroutine.

6.2.2. Data reduction

In the menu of the MASTER program there is an option to select Thomson scattering. This results in a call of the THOMWR subroutine controlling the calculation of plasma temperature and density. This subroutine also handles the printout of results on the terminal and optionally on the lineprinter. The THOMWR subroutine calls one of the subroutines THOMSO and THOMST. In THOMSO the actual calculations of results (temperature, density etc.)

are done while **THOMST** handles information on stray light measure-
ments.

6.2.2.1. Subroutine **THOMWR**. This subroutine first asks for
changes in the output options. The options include a choice of
one out of three output formats, optional output on lineprinter
and whether changes to the stray light calibration are allowed
or not. The selected options are coded into the byte variable
THOM.

Then **THOMWR** proceeds to test whether the present data set in-
cludes a plasma current. If so data are handled as for normal
temperature and density measurements, but if there is no current
these data are a measure of stray light. The time of the laser
pulse relative to start of plasma current is then found by
searching the plasma current trace for the monitor pulse from
the Constant Fraction Discriminator.

Finally **THOMWR** calls **THOMSO** or **THOMST** depending on the plasma
current and prints out the results. An example of output from
THOMWR is given in Fig. 10.

Shot = 121911.81

Electron temperature [eV]: 172. STD.DEV.INTV: 141.   226

Electron density [1.E19 m**-3]: 1.10 +/- 0.08

Time of measurement [msec]: 28.4

Laser pulse energy [J]: 1.49 +/- 0.10

Signal-to-noise ratios: 8.4   10.0

Ratio of scattering signals: 0.649 +/- 0.101

Number of scattered photons

    (per unit solid angle, per joule incident energy)

        channel 1:   3.12E + 05 +/- 3.74E + 04

        channel 2:   4.81E + 05 +/- 4.83E + 04

Number of plasma photons (per unit solid angle)

        channel 1:   6.56E + 04 +/- 1.55E + 04

        channel 2:   1.40E + 05 +/- 2.05E + 04

Raw data:

Laser monitor: 177   6

Channel 1   :   194   24

Channel 2   :   281   46

Figure 10. Output from subroutine THOMWR for plasma
shot no 121911.81

6.2.2.2. Subroutine THOMSO. The subroutine THOMSO first reads the data from the data file THOMSO.DAT. This file contains all calibration factors, tables, etc. for the calculation of temperature and density. Then the laser pulse energy is calculated by taking the difference between data from during the pulse and after the pulse and then multiply by the calibration factor.

The number of detected photoelectrons is calculated in a similar way. The standard deviation is estimated as the square root of the sum of the data from during and after the laser pulse corrected by the calibration factors. (The number of detected photoelectrons are distributed according to Poissons distribution

Through normalizing the number of photoelectrons by the laser
energy and using the calibration factor for optical transmission
of the collecting system, and finally subtracting the stray light
contribution, the number of scattered photons for each channel
from the scattering volume is found). The standard deviation on
these numbers are found using the deviation on photoelectrons,
on laser energy and on stray light.

The amount of light from the plasma is calculated similarly to
the scattered light using the data following the laser pulse.
These numbers do not enter the temperature and density calcula-
tions and are for information only.

The ratio of scattered light is calculated together with the
absolute lower and upper limit of the standard deviation inter-
val. By comparing this ratio with the precalculated ratio table
the temperature and standard deviation interval is found. The
density is found by comparing the sum of the scattered photons
with the equivalent values for the estimated temperature in the
table. The values in the table correspond to a density of 1.E17
m**-3.

6.2.2.3. Subroutine THOMST. This subroutine keeps a log of the
last 50 stray light measurements and updates the stray light
data in the data file THOMSO.DAT.

The last 50 stray light measurements are kept on a file THOMST.
DAT. First THOMST recalculates the mean stray light level from
these data and prints the information on the terminal. The s'tay
light level of the present measurement, corrected for laser
energy, is calculated and printed for comparison. The new cali-
bration data based on the last 49 recorded data sets and the
present shot is also displayed on the terminal. Finally a ques-
tion giving the option of including the data from the present
measurement in the calibration is presented.

If an update of the stray light calibration is made the new cali-
bration data are written to the data file THOMSO.DAT and the pre-

sent dataset is included in the log of stray light measurements. This log (when filled with 50 measurements) is maintained on a first-in first-out basis.

6.2.2.4. Data file THOMSO.DAT.

This file contains all calibration data, parameter settings, etc. for the diagnostic. The program THOM3.FOR gives a listing of all the data in the file as shown in the table below.

To create a new data file from scratch it is convenient to use the program THOM1.FOR. Single value editing of the data file is easily done by editing and running the program THOM2.FOR.

Output from THOM3		COMMENTS
CH, PED, GAIN: 0 5.209156	0.4694981	Calibration
| | |	|	data for
CH, PED, GAIN: 11 5.451578	0.4557599	LeCroy ADC
PEDTIM: 80.00000		Gate length for pedestral calib.
EFAK : 8.7000001E-03		Energy monitor calib.
EPHEL1: 0.6290000		Charge/photon CH1
EPHEL2: 0.4660000		Charge/photon CH2
TRANS1: 3660.000		Transmission CH1
TRANS2: 3000.000		Transmission CH2
VOL : 8.3200000E-02		Not used
TFAK1 : 13.23740		Not used
TFAK2 : 1.134600		Not used
CH1U : 692.3000		Upper limit CH1
CH1L : 684.6000		Lower limit CH1
CH2U : 682.6000		Upper limit CH2
CH2L : 658.3000		Lower limit CH2
HVOL : 1900.000		PMT high voltage
NTAB : 50		Length of temperature table
STR1 : 0.0000000		Stray light CH1
STR2 : 0.0000000		Stray light CH2

Output from THOM3			COMMENTS		
DSTR1 : 0.0000000			Stand.dev on STR1		
DSTR2 : 0.0000000			Stand.dev on STR2		
DEFAK : 6.4999998E-02			Stand.dev on EFAK		
TEMP,R,N1,N2 : 10.00000	91.25423	5384	59	Table of	
TEMP,R,N1,N2 : 20.00000	11.18053	5512	493	scattering	
I	I	I	I	I	data as
TEMP,R,N1,N2 : 489.0000	0.3957292	1742	4402	function of	
TEMP,R,N1,N2 : 500.0000	0.3932969	1725	4386	temperature	

6.2.3. Calibration of LeCroy 2250L ADC

The gain and pedestral of the charge integrating ADC is presently measured using the internal test function (CAMAC F25) of the module. For this purpose a DC voltage must be applied to the front panel test input. The test voltage should be varied in the range 0-20 V to allow for full-scale readings of the channels. In order to be able to go through the calibration procedure a CAMAC Inhibit function must also be available. The flow of operations for the calibration procedure is described in the program THOM4.FOR which should be self-explaining. For further information on the module and its calibration the reader is referred to the manual. The position of the ADC in the CAMAC crate is taken to be station No. 4 in this program.

The basics of the procedure are measurements of signal levels at different test voltage levels. The data for each channel are then approximated by a least-square fit to a line, giving the gain and pedestral. To improve statistics in the line fit several measurements are automatically made at each test voltage level.

The new calibration data are optionally written on the data file THOMSO.DAT.

The above calibration procedure was made before the Gate Pulse Trigger module was available to the system. Now a new procedure employing the ability to generate an external gate pulse via a CAMAC command would be desirable (see Section 5.1).

6.2.4. Calculation of expected data for table

The program THOMO.FOR calculates the number of scattered photons in two wavelength regions (channel 1 and 2) for Thomson scattering in a plasma with density 1.E17 m-3 and for a ruby laser pulse of 1 joule.

The calculations are presently done in the temperature range 10-500 eV with stepsize 10 eV. Apart from calculating the number of scattered photons at each temperature, the ratio of these two numbers is also calculated. The results are optionally written to the file THOMSO.DAT, from where they are later used in the temperature and density estimate.

A low temperature, Gaussian approximation to the spectral density function (Sheffield, 1975) is used in this program.

REFERENCES

ADAMS, W.E. (1968). Pockels Cells: Theory, Test Procedures, Characteristics, UCRL-50463.

GADEBERG, M. (1983). Thomsonspredning på høj- og lavtemperatur plasma, Risø-M-2378, 96 pp.

KØCHNER, W. (1976). Solid-State Laser Engineering. Springer-Verlag, New York.

SHEFFIELD, J. (1975). Plasma Scattering of Electromagnetic Radiation, Academic Press, New York.

APPENDIX A

Subroutine THOMWR

This appendix contains a listing of the THOMWR subroutine. This subroutine is linked to the MASTER program, and it is called when Thomson scattering results are to be calculated. The subroutines THOMSO and THOMST are called from this subroutine.

In the call of THOMWR, IFIL1 and IFIL2 are the input and output unit numbers, THOM is the output option code, and NAVN is the name of the present plasma shot.

```
        V02.5-2    Wed 22-Jun-83 10:22:06

        SUBROUTINE THOMWR(IFIL1,IFIL2,THOM,NAVN)
        REAL VFS(8),SWA(8),SWB(8),NUL(8)
        INTEGER IS(8)
        BYTE NAVNUD(10,8),RD(1024,8),C8,C9,C10,TSTRL
        INTEGER ILAS(6,4)
        REAL RAT(3),T(3)
        BYTE TEST,THOM,NAVN(10)
        COMMON NAVNUD,VFS,SWA,SWB,NUL,IS,RD,ILAS,NTRAC
        COMMON/WAR/ T,DENSI,DDENSI,TID1,TID2,TID3,E,DE,PHEL1,DPHEL1,
       *    PHEL2,DPHEL2,RAT,DRAT,SCAT1,DSCAT1,SCAT2,DSCAT2,PLAS1,DPLAS1,
       *    PLAS2,DPLAS2,K,II,IOPTIO
        DATA C8,C9,C10/'C','U','R'/
        ITIME=0


*********** SELECT OUTPUT OPTION ************

        WRITE(7,290)
        READ(IFIL1,300) TEST
        WRITE(IFIL2,300) TEST
        IF(TEST.NE.'Y') GOTO 20
        WRITE(7,310)
        READ(IFIL1,320) I
        WRITE(IFIL2,320) I
        IF(I.LT.1.OR.I.GT.3) GOTO 10
        WRITE(7,330)
        READ(IFIL1,300) TEST
        WRITE(IFIL2,300) TEST
        IF(TEST.EQ.'Y') I=I+10
        THOM=I
        WRITE(7,350)
        READ(IFIL1,300) TEST
        WRITE(IFIL2,300) TEST
        IF(TEST.EQ.'Y') THOM=THOM+100
```

```
20      K=7
        I=THOM
        I=MOD(I,10)
        IOPTIO=THOM/10
C
C
C       *********** TEST FOR PLASMA CURRENT ON SHOT ************
C
        X=0.
        TSTRL=1
        IC=0
        DO 30 II=1,NTRAC
30      IF(C8.EQ.NAVNUD(1,II).AND.C9.EQ.NAVNUD(2,II).AND.C10.EQ.
     *      NAVNUD(3,II)) IC=II
        IF(IC.EQ.0) GOTO 50
        DO 40 II=1,1024
40      X=X+RD(II,IC)+128-NUL(IC)
        IF(ABS(X).GT.5000.) TSTRL=0
C
C
C       *********** PERFORM CALTULATIONS ************
C
50      DO 160 II=1,3,2
        IF(ILAS(1,II).LT.20) GOTO 170
        IF(II.EQ.3.AND.TSTRL.EQ.0.AND.IOPTIO.NE.1) PAUSE
C
C       *********** CALCULATE TIME OF LASER PULSE **********
C
        DO 60 I=ITIME,1023
        IF(RD(I,IC).EQ.127) GOTO 70
60      CONTINUE
        TYPE 90
        GOTO 100
70      ISS=IS(IC)
        IF(IC.GE.7) ISS=1024-IS(IC)*100
        TID3=(I-ISS)*SWA(IC)
        DO 80 ITIME=I,1023
        IF(RD(ITIME,IC).LT.127) GOTO 100
80      CONTINUE
        TYPE 90
90      FORMAT(' *-* ERROR IN CALCULATION OF TIME OF LASER PULSE ***')
100     IF(TSTRL.GT.0) GOTO 130
        CALL THOMSO(ILAS,IFIL1,IFIL2,THOM,NAVN)
110     WRITE(K,200) T(1),T(2),T(3)
        WRITE(K,210) DENSI,DDENSI
        WRITE(K,220) TID3
        WRITE(K,230) E,DE
        IF(I.EQ.1) GOTO 140
C       WRITE(K,190) TID1,TID2
        WRITE(K,250) SCAT1/DSCAT1,SCAT2/DSCAT2
        WRITE(K,260) RAT(1),DRAT
        WRITE(K,270) SCAT1,DSCAT1,SCAT2,DSCAT2
        WRITE(K,280) PLAS1,DPLAS1,PLAS2,DPLAS2
```

```
120     IF(I.LE.2) GOTO 140
        WRITE(K,*) ' '
        WRITE(K,*) 'RAW DATA:'
        WRITE(K,*) 'LASERMONITOR :',ILAS(1,II),ILAS(1,II+1)
        WRITE(K,*) 'CHANNEL   1   :',ILAS(2,II),ILAS(2,II+1)
        WRITE(K,*) 'CHANNEL   2   :',ILAS(4,II),ILAS(4,II+1)
C       WRITE(K,*) 'GATE WIDTH   :',ILAS(5,II),ILAS(5,II+1)
C       WRITE(K,*) 'TIME OF SHOT :',ILAS(6,II),ILAS(6,II+1)
        WRITE(K,*) ' '
        GOTO 140
130     CALL THOMST(ILAS,IFIL1,IFIL2,THOM,NAVN)
        GOTO 120
C
C
C       *********** TEST FOR OUTPUT ON LP ************
C
140     IF(K.EQ.7) GOTO 150
        K=7
        GOTO 160
150     IF(IOPTIO.NE.1) GOTO 160
        ILP=1
        K=6
        WRITE(6,190) NAVN
        IF(TSTRL.GT.O) GOTO 130
        GOTO 110
160     CONTINUE
C
C
C       *********** LAST OUTPUT ON LP ? ************
C
170     IF(ILP.NE.1) GOTO 180
        WRITE(7,340)
        READ(IFIL1,300) TEST
        WRITE(IFIL2,300) TEST
        IF(TEST.EQ.'Y') CLOSE(UNIT=6)
        IF(TEST.EQ.'Y') ILP=0
180     IF(TSTRL.EP.O.AND.IOPTIO.NE.1)
        *     PAUSE 'NO MORE THOMSON SCATTERING DATA ON THIS SHOT'
190     FORMAT(/,'0  SHOT    ',10A)
200     FORMAT(' ',/,' ELECTRON TEMPERATURE [eV] :        ',F5.0,
        *     ' STD.DEV.INTV:',2F6.0)
210     FORMAT(' ELECTRON DENSITY [1.E19 m**-3] : ',F5.2,' +/-',F5.2)
220     FORMAT(' TIME OF MEASUREMENT [msec]:       ',F4.1)
230     FORMAT(' LASER PULSE ENERGY [J] :          ',F4.2,' +/-',F4.2)
240     FORMAT('0GATE WIDTHS [nsec] :           ',F4.0,3X,F4.0)
250     FORMAT(' SIGNAL-TO-NOISE RATIOS:          ',F4.1,3X,F4.1)
260     FORMAT(' RATIO OF SCATTERING SIGNALS:     ',F6.3,' +/-',F5.3)
270     FORMAT(' NUMBER OF SCATTERED PHOTONS',/,
        *     '        (PER UNIT SOLID ANGLE, PER JOULE INCIDENT ENERGY )',/,
        *     '            CHANNEL  1 : ',1PG17.2,' +/-',1PG8.2,/,
        *     '            CHANNEL  2 : ',1PG17.2,' +/-',1PG8.2'
280     FORMAT(' NUMBER OF PLASMA PHOTONS (PER UNIT SOLID ANGLE)',/,
        *     '            CHANNEL  1 : ',1PG17.2,' +/-',1PG8.2,/,
```

```
                   *    '              CHANNEL  2 : ',1PG17.2,' +/-',1PG8.2)
0128   290    FORMAT('0ANY CHANGES IN OUTPUT ? ',$)
0129   300    FORMAT(A)
0130   310    FORMAT('0SELECT OUTPUT FORMAT :',/,
              *    '   1: CONDENSED LISTING OF RESULTS',/,
              *    '   2: EXTENDED  LISTING OF RESULTS',/,
              *    '   3: FULL LISTING OF DATA')
0131   320    FORMAT(I2)
0132   330    FORMAT(' OUTPUT ON LINEPRINTER ? ',$)
0133   340    FORMAT(' LAST OUTPUT ON LINEPRINTER ? ',$)
0134   350    FORMAT(' ALLOWANCE TO CORRECT STRAY LIGHT CALLIBRATION ? ',$)
0135          END
```

FORTRAN IV   Storage Map for Program Unit THOMWR

Local Variables, .PSECT $DATA, Size = 000056 (23. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
C10	L*1	000012	C8	L*1	000010	C9	L*1	000011
I	I*2	000026	IC	I*2	000034	IFIL1	I*2 @	000000
IFIL2	I*2 @	000002	ILP	I*2	000040	ISS	I*2	000036
ITIME	I*2	000024	TEST	L*1	000023	THOM	L*1 @	000004
TSTRL	L*1	000022	X	R*4	000030			

COMMON Block /   /, Size = 020422 (4233. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
NAVNUD	L*1	000000	VFS	R*4	000120	SWA	R*4	000160
SWB	R*4	000220	NUL	R*4	000260	IS	I*2	000320
RD	L*1	000340	ILAS	I*2	020340	NTRAC	I*2	020420

COMMON Block /WAR   /, Size = 000156 (55. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
T	R*4	000000	DENSI	R*4	000014	DDENSI	R*4	000020
TID1	R*4	000024	TID2	R*4	000030	TID3	R*4	000034
E	R*4	000040	DE	R*4	000044	PHEL1	R*4	000050
DPHEL1	R*4	000054	PHEL2	R*4	000060	DPHEL2	R*4	000064
RAT	R*4	000070	DRAT	R*4	000104	SCPT1	R*4	000110
DSCAT1	R*4	000114	SCAT2	R*4	000120	DSCAT2	R*4	000124
PLAS1	R*4	000130	DPLAS1	R*4	000134	PLAS2	R*4	000140
DPLAS2	R*4	000144	K	I*2	000150	II	I*2	000152
IOPTIO	I*2	000154						

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
ILAS	I*2 Vec	.$$$$.	020340	000060 (24.)	(6,4)
IS	I*2	.$$$$.	000320	000020 (8.)	(8)
NAVN	L*1 @	$DATA	000006	000012 (5.)	(10)
NAVNUD	L*1 Vec	.$$$$.	000000	000120 (40.)	(10,8)

NUL	R*4		.$$$$.	000260	000040	(	16.)	(8)
RAT	R*4		WAR	000070	000014	(	6.)	(3)
RD	L*1	Vec	.$$$$.	000340	020000	(	4096.)	(1024,8)
SWA	R*4		.$$$$.	000160	000040	(	16.)	(8)
SWB	R*4		.$$$$.	000220	000040	(	16.)	(8)
T	R*4		WAR	000000	000014	(	6.)	(3)
VFS	R*4		.$$$$.	000120	000040	(	16.)	(8)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ABS	R*4	MOD	I*2	THOMSO	R*4	THOMST	R*4		

APPENDIX B

Subroutine THOMSO

This appendix contains a listing of the THOMSO subroutine. This subroutine is linked to the MASTER program, and it is called by the THOMWR subroutine. THOMSO calculates the temperature and density from the Thomson scattering data.

```
RAN IV      V02.5-2    Wed 22-Jun-83 10:21:29

        SUBROUTINE THOMSO(ILAS, IFIL1, IFIL2, THOM, NAVN)
        INTEGER ILAS(6,4),N1(50),N2(50)
        REAL PED(12),GAIN(12),TEMP(50),R(50),RAT(3),T(3)
        BYTE TEST,THOM,NAVN(10)
        COMMON/WAR/ T,DENSI,DDENSI,TID1,TID2,TID3,E,DE,PHEL1,DPHEL1,
     *      PHEL2,DPHEL2,RAT,DRAT,SCAT1,DSCAT1,SCAT2,DSCAT2,PLAS1,DPLAS1,
     *      PLAS2,DPLAS2,K,II
        OPEN(UNIT=15,NAME='DL0:THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *      RECORDSIZE=256)
        READ(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *      VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *      STR1,STR2,DSTR1,DSTR2,DEFAC
        CLOSE(UNIT=15)
C
C
C       *********** CALCULATE TIMES AND ENERGY ************
C
C       TID1=ILAS(5,II  )/(PED(5)/PEDTIM+VOL*1000./GAIN(5)/50.)
C       TID2=ILAS(5,II+1)/(PED(5)/PEDTIM+VOL*1000./GAIN(5)/50.)
C       TT=TID1/TID2
        TT=1.
C       TID3=TFAK1*((ILAS(6,II  )-TID1/PEDTIM*PED(6))/TID1)**TFAK2
C       TID4=TFAK1*((ILAS(6,II+1)-TID2/PEDTIM*PED(6))/TID2)**TFAK2     .
C       TID3=(TID3+TID4)/2.
        E=(ILAS(1,II)-TT*ILAS(1,II+1))*EFAK
        DE=E*DEFAC
C
C
C       *********** CALCULATE NUMBER OF PHOTONS ************
C
        PHEL1=(ILAS(2,II)-TT*ILAS(2,II+1))*GAIN(2)/EPHEL1
        PHEL2=(ILAS(4,II)-TT*ILAS(4,II+1))*GAIN(4)/EPHEL2
        DPHEL1=SQRT((ILAS(2,II)+TT*ILAS(2,II+1))*GAIN(2)/EPHEL1)
        DPHEL2=SQRT((ILAS(4,II)+TT*ILAS(4,II+1))*GAIN(4)/EPHEL2)
        SCAT1=TRANS1*PHEL1/E-STR1
        SCAT2=TRANS2*PHEL2/E-STR2
        DSCAT1=SQRT((TRANS1*DPHEL1/E)**2+(TRANS1*PHEL1*DEFAC/E)**2
     *            +DSTR1**2)
```

```
      DSCAT2=SQRT((TRANS2*DPHEL2/E)**2+(TRANS2*PHEL2*DEFAC/E)**2
     *          +DSTR2**2)
      S1=(ILAS(2,II+1)-TID2/PEDTIM*PED(2))*GAIN(2)/EPHEL1
      S2=(ILAS(4,II+1)-TID2/PEDTIM*PED(4))*GAIN(4)/EPHEL2
      PLAS1=TRANS1*S1
      PLAS2=TRANS2*S2
      S1=ABS(S1)
      S2=ABS(S2)
      DPLAS1=TRANS1*SQRT(S1)
      DPLAS2=TRANS2*SQRT(S2)
C
C
C     *********** FIND TEMPERATURES AND DENSITY ***********
C
      IF(SCAT2.EQ.0.) RETURN
      RAT(1)=SCAT1/SCAT2
      DRAT=RAT(1)*SQRT((DSCAT1/SCAT1)**2+(DSCAT2/SCAT2)**2)
      RAT(2)=RAT(1)+DRAT
      RAT(3)=RAT(1)-DRAT
      DO 530 J=1,3
      IF(RAT(J).GT.0.) GOTO 500
      T(J)=9999.
      GOTO 530
500   DO 510 JJ=2,NTAB-1
      IF(RAT(J).GT.R(JJ)) GOTO 520
510   CONTINUE
520   T(J)=TEMP(JJ-1)+
     *     (TEMP(JJ)-TEMP(JJ-1))/(R(JJ)-R(JJ-1))*(RAT(J)-R(JJ-1))
      IF(J.EQ.1) AN=FLOAT(N1(JJ-1))+
     *     FLOAT(N1(JJ)-N1(JJ-1))/(R(JJ)-R(JJ-1))*(RAT(J)-R(JJ-1))+
     *     FLOAT(N2(JJ-1))+
     *     FLOAT(N2(JJ)-N2(JJ-1))/(R(JJ)-R(JJ-1))*(RAT(J)-R(JJ-1))
530   CONTINUE
      DENSI=0.
      DDENSI=0.
      IF(AN.NE.0) DENSI=(SCAT1+SCAT2)/AN/100.
      IF(AN.NE.0) DDENSI=SQRT(DSCAT1**2+DSCAT2**2)/AN/100.
      END
```

FORTRAN IV   Storage Map for Program Unit THOMSO

Local Variables, .PSECT $DATA, Size = 001546 (435. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
AN	R*4	001450	CH1L	R*4	001362	CH1U	R*4	001356
CH2L	R*4	001372	CH2U	R*4	001366	DEFAC	R*4	001424
DSTR1	R*4	001414	DSTR2	R*4	001420	EFAK	R*4	001316
EPHEL1	R*4	001322	EPHEL2	R*4	001326	HVOL	R*4	001376
IFIL1	I*2 @	000002	IFIL2	I*2 @	000004	J	I*2	001444
JJ	I*2	001446	NTAB	I*2	001402	PEDTIM	R*4	001312
STR1	R*4	001404	STR2	R*4	001410	S1	R*4	001434

S2	R*4	001440	TEST	L*1	001310	TFAK1	R*4	001346
TFAK2	R*4	001352	THOM	L*1 @	000006	TRANS1	R*4	001332
TRANS2	R*4	001336	TT	R*4	001430	VOL	R*4	001342

COMMON Block /WAR /, Size = 000154 (54. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
T	R*4	000000	DENSI	R*4	000014	DDENSI	R*4	000020
TID1	R*4	000024	TID2	R*4	000030	TID3	R*4	000034
E	R*4	000040	DE	R*4	000044	PHEL1	R*4	000050
DPHEL1	R*4	000054	PHEL2	R*4	000060	DPHEL2	R*4	000064
RAT	R*4	000070	DRAT	R*4	000104	SCAT1	R*4	000110
DSCAT1	R*4	000114	SCAT2	R*4	000120	DSCAT2	R*4	000124
PLAS1	R*4	000130	DPLAS1	R*4	000134	PLAS2	R*4	000140
DPLAS2	R*4	000144	K	I*2	000150	II	I*2	000152

Local and COMMON Arrays:

Name	Type		Section	Offset	------Size-----		Dimensions
GAIN	R*4		$DATA	000402	000060 (	24.)	(12)
ILAS	I*2	Vec@	$DATA	000000	000060 (	24.)	(6,4)
NAVN	L*1	@	$DATA	000010	000012 (	5.)	(10)
N1	I*2		$DATA	000012	000144 (	50.)	(50)
N2	I*2		$DATA	000156	000144 (	50.)	(50)
PED	R*4		$DATA	000322	000060 (	24.)	(12)
R	R*4		$DATA	000772	000310 (	100.)	(50)
RAT	R*4		WAR	000070	000014 (	6.)	(3)
T	R*4		WAR	000000	000014 (	6.)	(3)
TEMP	R*4		$DATA	000462	000310 (	100.)	(50)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ABS	R*4	FLOAT	R*4	SQRT	R*4				

APPENDIX C

Subroutine THOMST

This appendix contains a listing of the THOMST subroutine. This subroutine is linked to the MASTER program, and it is called from the THOMWR subroutine. THOMST handles information on stray light measurements and maintains a log of these measurements in file THOMST.DAT. It also updates the stray light calibration data in the data file THOMSO.DAT. For calculation of the mean stray light level from the stored data the subroutine MEAN is called. This subroutine calculates the mean and standard deviation of a set of data.

```
        V02.5-2     Wed 22-Jun-83 10:33:34

        SUBROUTINE THOMST(ILAS,IFIL1,IFIL2,THOM,NAVN)
        INTEGER ILAS(6,4),N1(50),N2(50)
        REAL PED(12),GAIN(12),TEMP(50),R(50),RAT(3),T(3)
        REAL STRAL1(50),STRAL2(50),STRAL3(50),STRAL4(50)
        BYTE TEST,THOM,NAVN(10)
        COMMON/WAR/ T,DENSI,DDENSI,TID1,TID2,TID3,E,DE,PHEL1,DPHEL1,
       *     PHEL2,DPHEL2,RAT,DRAT,SCAT1,DSCAT1,SCAT2,DSCAT2,PLAS1,DPLAS1,
       *     PLAS2,DPLAS2,K,II,IOPTIO,STRAL1,STRAL2,STRAL3,STRAL4
        OPEN(UNIT=15,NAME='DLO:THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
       *     RECORDSIZE=256)
        READ(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
       *     VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
       *     STR1,STR2,DSTR1,DSTR2,DEFAC
        CLOSE(UNIT=15)


        ********** CALCULATE TIMES AND ENERGY ************

        TID1=ILAS(5,II  )/(PED(5)/PEDTIM+VOL*1000./GAIN(5)/50.)
        TID2=ILAS(5,II+1)/(PED(5)/PEDTIM+VOL*1000./GAIN(5)/50.)
        TT=TID1/TID2
        TT=1.
        TID3=TFAK1*((ILAS(6,II  )-TID1/PEDTIM*PED(6))/TID1)**TFAK2
        TID4=TFAK1*((ILAS(6,II+1)-TID2/PEDTIM*PED(6))/TID2)**TFAK2
        TID3=(TID3+TID4)/2.
        E=(ILAS(1,II)-TT*ILAS(1,II+1))*EFAK
        DE=E*DEFAC
        WRITE(K,930) E,DE


        ************ CALCULATE NUMBER OF PHOTONS ************

        PHEL1=(ILAS(2,II)-TT*ILAS(2,II+1))*GAIN(2)/EPHEL1
        PHEL2=(ILAS(4,II)-TT*ILAS(4,II+1))*GAIN(4)/EPHEL2
```

```
DPHEL1=SQRT((ILAS(2,II)+TT*ILAS(2,II+1))*GAIN(2)/EPHEL1)
DPHEL2=SQRT((ILAS(4,II)+TT*ILAS(4,II+1))*GAIN(4)/EPHEL2)
SCAT1=TRANS1*PHEL1/E
SCAT2=TRANS2*PHEL2/E
DSCAT1=SQRT((TRANS1*DPHEL1/E)**2+(TRANS1*PHEL1*DEFAC/E)**2)
DSCAT2=SQRT((TRANS2*DPHEL2/E)**2+(TRANS2*PHEL2*DEFAC/E)**2)


*********** GET OLD CALIBRATION ************

OPEN(UNIT=15,NAME='DL0:THOMST.DAT',ACCESS='DIRECT',TYPE='OLD',
*     RECORDSIZE=128)
READ(15'1) STRAL1,STRAL2,NTAB1
CLOSE(UNIT=15)
CALL MEAN(X1,DX1,STRAL1,NTAB1)
CALL MEAN(X2,DX2,STRAL2,NTAB1)
IF(X1.NE.STR1.OR.X2.NE.STR2.OR.DX1.NE.DSTR1.OR.DX2.NE.DSTR2)
*     WRITE(K,910) X1,DX1,X2,DX2


*********** CALCULATE NEW CALIBRATION ************

NMAX=NTAB1+1
IF(NMAX.GT.50) NMAX=50
DO 900 I=2,NMAX
STRAL3(I)=STRAL1(I-1)
STRAL4(I)=STRAL2(I-1)
STRAL3(1)=SCAT1
STRAL4(1)=SCAT2
CALL MEAN(X1,DX1,STRAL3,NMAX)
CALL MEAN(X2,DX2,STRAL4,NMAX)
WRITE(K,920) NTAB1,STR1,DSTR1,STR2,DSTR2,
*     SCAT1,DSCAT1,SCAT2,DSCAT2,NMAX,X1,DX1,X2,DX2
IF(II.EQ.1.AND.IOPTIO.NE.1) PAUSE
IF(II.EQ.3.AND.IOPTIO.NE.1)
*     PAUSE 'NO MORE STRAY LIGHT DATA ON THIS SHOT'
IF(IOPTIO.LT.10) RETURN


*********** STORE RESULTS ************

OPEN(UNIT=15,NAME='DL0:THOMST.DAT',ACCESS='DIRECT',TYPE='OLD',
*     RECORDSIZE=128)
WRITE(15'1) STRAL3,STRAL4,NMAX
CLOSE(UNIT=15)
OPEN(UNIT=15,NAME='DL0:THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
*     RECORDSIZE=256)
WRITE(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
*     VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
*        X1,X2,DX1,DX2,DEFAC
CLOSE(UNIT=15)
FORMAT(//,' ***** WARNING *****',/,
*     ' DIFFERENCE IN STRAY LIGHT CALIBRATION',/,
```

```
*      ' DATA FROM "DLO:THOMST.DAT":',/,
*      '    CHANNEL   1 : ',1PG17.2,' +/- ',1PG8.2,/,
*      '    CHANNEL   2 : ',1PG17.2,' +/- ',1PG8.2)
  FORMAT(//,
*      ' OLD STRAY LIGHT CALIBRATION (MEAN OVER ',I2,' PULSES) : ',/,
*      '    CHANNEL   1 : ',1PG17.2,' +/- ',1PG8.2,/,
*      '    CHANNEL   2 : ',1PG17.2,' +/- ',1PG8.2,/,
*      'OSTRAY LIGHT ON THIS PULSE : ',/,
*      '    CHANNEL   1 : ',1PG17.2,' +/- ',1PG8.2,/,
*      '    CHANNEL   2 : ',1PG17.2,' +/- ',1PG8.2,/,
*      'ONEW STRAY LIGHT CALIBRATION (MEAN OVER ',I2,' PULSES) : ',/,
*      '    CHANNEL   1 : ',1PG17.2,' +/- ',1PG8.2,/,
*      '    CHANNEL   2 : ',1PG17.2,' +/- ',1PG8.2,/)
  FORMAT(' LASER ENERGY [J] : ',F4.2,' +/- ',F4.2)
  END
```

FORTRAN IV   Storage Map for Program Unit THOMST

Local Variables, .PSECT $DATA, Size = 001514 (422. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
CH1L	R*4	001364	CH1U	R*4	001360	CH2L	R*4	001374
CH2U	R*4	001370	DEFAC	R*4	001426	DSTR1	R*4	001416
DSTR2	R*4	001422	DX1	R*4	001444	DX2	R*4	001454
EFAK	R*4	001320	EPHEL1	R*4	001324	EPHEL2	R*4	001330
HVOL	R*4	001400	I	I*2	001462	IFIL1	I*2 @	000002
IFIL2	I*2 @	000004	NMAX	I*2	001460	NTAB	I*2	001404
NTAB1	I*2	001436	PEDTIM	R*4	001314	STR1	R*4	001406
STR2	R*4	001412	TEST	L*1	001312	TFAK1	R*4	001350
TFAK2	R*4	001354	THOM	L*1 @	000006	TRANS1	R*4	001334
TRANS2	R*4	001340	TT	R*4	001432	VOL	R*4	001344
X1	R*4	001440	X2	R*4	001450			

COMMON Block /WAR   /, Size = 001616 (455. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
T	R*4	000000	DENSI	R*4	000014	DDENSI	R*4	000020
TID1	R*4	000024	TID2	R*4	000030	TID3	R*4	000034
E	R*4	000040	DE	R*4	000044	PHEL1	R*4	000050
DPHEL1	R*4	000054	PHEL2	R*4	000060	DPHEL2	R*4	000064
RAT	R*4	000070	DRAT	R*4	000104	SCAT1	R*4	000110
DSCAT1	R*4	000114	SCAT2	R*4	000120	DSCAT2	R*4	000124
PLAS1	R*4	000130	DPLAS1	R*4	000134	PLAS2	R*4	000140
DPLAS2	R*4	000144	K	I*2	000150	II	I*2	000152
IOPTIO	I*2	000154	STRAL1	R*4	000156	STRAL2	R*4	000466
STRAL3	R*4	000776	STRAL4	R*4	001306			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
GAIN	R*4	$DATA	000402	000060 (24.)	(12)

ILAS	I*2	Vec@	$DATA	000000	000060	(	24.)	(6,4)
NAVN	L*1	@	$DATA	000010	000012	(	5.)	(10)
N1	I*2		$DATA	000012	000144	(	50.)	(50)
N2	I*2		$DATA	000156	000144	(	50.)	(50)
PED	R*4		$DATA	000322	000060	(	24.)	(12)
R	R*4		$DATA	000772	000310	(	100.)	(50)
RAT	R*4		WAR	000070	000014	(	6.)	(3)
STRAL1	R*4		WAR	000156	000310	(	100.)	(50)
STRAL2	R*4		WAR	000466	000310	(	100.)	(50)
STRAL3	R*4		WAR	000776	000310	(	100.)	(50)
STRAL4	R*4		WAR	001306	000310	(	100.)	(50)
T	R*4		WAR	000000	000014	(	6.)	(3)
TEMP	R*4		$DATA	000462	000310	(	100.)	(50)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
MEAN	I*2	SQRT	R*4						

FORTRAN IV   VO2.5-2   Wed 22-Jun-83 10:34:02

```
0001            SUBROUTINE MEAN(X,DX,A,NTAB)
0002            REAL A(NTAB)
        C
        C
        C       ROUTINE CALCULATES THE MEAN AND STANDARD DEVIATION (X,DX)
        C       OF THE NUMBERS IN ARRAY A.
        C
0003            S1=0.
0004            S2=0.
0005            X=0.
0006            DX=0.
0007            IF(NTAB.LE.0) RETURN
0009            DO 940 I=1,NTAB
0010            S1=S1+A(I)
0011    940     S2=S2+A(I)**2
0012            X=S1/NTAB
0013            IF(NTAB-1.GT.0) DX=(S2-NTAB*X**2)/(NTAB-1)
0015            IF(DX.GT.0) DX=SQRT(DX)
0017            END
```

FORTRAN IV   Storage Map for Program Unit MEAN

Local Variables, .PSECT $DATA, Size = 000032 (13. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
DX	R*4 @	000002	I	I*2	000022	NTAB	I*2 @	000006
S1	R*4	000012	S2	R*4	000016	X	R*4 @	000000

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
A	R*4	@ $DATA	000004	**** (**)	(NTAB)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
SQRT	R*4								

APPENDIX D

Program THOMO

This appendix contains a listing of the THOMO program. The program
generates the table of expected scattering data used for estimating
the temperature and density. The main program calls the subroutine
ROMINT for Romberg integration of the function F, which is the
spectral density function.

      V02.5-2   Wed 22-Jun-83 10:18:34

```
PROGRAM THOMO
REAL PED(12),GAIN(12),TEMP(50),TEMPO(50),R(50),RO(50)
INTEGER N1(50),N10(50),N2(50),N20(50)
LOGICAL*1 DA(9),TI(8),RS,US,AA
DATA RS,US/30,31/
WRITE(7,99)
FORMAT('0')
WRITE(7,100) 1
FORMAT(' ENTER CHANNEL  ',I1,' (LMIN,LMAX) IN nm (2F9.4): ',$)
READ(5,101) CH1L,CH1U
WRITE(7,100) 2
READ(5,101) CH2L,CH2U
FORMAT(3F9.4)
WRITE(7,102)
FORMAT(' ENTER TEMPERATURE INTERVAL (TMIN,TMAX)',/,
*'    IN eV FOR CALCULATION (2F9.4) :'$)
READ(5,101) TMIN,TMAX
DT=(TMAX-TMIN)/49.
CALL DATE(DA)
CALL TIME(TI)
WRITE(6,103) DA,TI,US,RS,CH1L,CH1U,CH2L,CH2U,TMIN,TMAX,DT
WRITE(7,103) DA,TI,' ',' ',CH1L,CH1U,CH2L,CH2U,TMIN,TMAX,DT
FORMAT(' ',9A,T80,8A,//,T10,A,'SPECTROMETER RESPONSE',A,
*,//,T10,'Calculation of number of detected photoelectrons in',/,
*T10,'channel  1 : ',F8.2,' nm - ',F8.2,' nm',/,
*T10,'channel  2 : ',F8.2,' nm - ',F8.2,' nm',//,
*T10,'calculated in the temperature range',/,
*T10,F4.0,' eV - ',F4.0,' eV with stepsize ',F4.0,' eV',///,
*T10,'T (eV)',T18,'N1 (counts)',T33,'N2 (counts)',T48,'R = N1/N2',
*T60,'DELTA(R)/R (%)')        !,T77,'Ntotal (counts)')
TMIN=TMIN/1000.
TMAX=TMAX/1000.
DT=DT/1000.
DO 20 J=1,50
TEMP(J)=TMIN+DT*(J-1)
MAXE=15
CALL ROMINT(XX,ERR,.001,CH1L,CH1U,N,MAXE,TEMP(J))
```

```
      MAXE=15
      CALL RDMINT(YY,ERR,.001,CH2L,CH2U,N,MAXE,TEMP(J))
      MAXE=15
      CALL RDMINT(ZZ,ERR,.0001,500.,900.,N,MAXE,TEMP(J))
      XX=XX*1.7132E4        ! 1.7132E6 PHOTONS @ 1 JOULE
      YY=YY*1.7132E4        ! AND 1.E19 M-3 AND PER SRAD
      ZZ=ZZ*1.7132E4
      TEMP(J)=1000.*TEMP(J)
      N1(J)=IFIX(XX+.5)
      N2(J)=IFIX(YY+.5)
      R(J)=10000.
      DR=R(J)
      IF(N1(J).EQ.0.OR.N2(J).EQ.0) GOTO 21
      R(J)=FLOAT(N1(J))/FLOAT(N2(J))
      DR=SQRT(1./N1(J)+1./N2(J))*100.
      WRITE(6,104) TEMP(J),N1(J),N2(J),R(J),DR        !,IFIX(ZZ+.5)
      WRITE(7,104) TEMP(J),N1(J),N2(J),R(J),DR        !,IFIX(ZZ+.5)
      FORMAT(T10,F4.0,T18,I6,T33,I6,T48,F9.4,T60,F9.4,T77,I6)
      CONTINUE
      CLOSE(UNIT=6)
      WRITE(7,*) 'TO SAVE RESULTS ON "THOMSO.DAT" TYPE "Y"'
      READ(5,105) AA
      FORMAT(A)
      IF(AA.NE.'Y') GOTO 10
      OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *    RECORDSIZE=256)
      READ(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *    VOL,TFAK1,TFAK2,CH1UO,CH1LO,CH2UO,CH2LO,HVOL,NTAB,
     *    TEMPO,N1O,N2O,RO,STR1,STR2,DSTR1,DSTR2
      CLOSE(UNIT=15)
      NTAB=50
      OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='NEW',ACCESS='DIRECT',
     *    RECORDSIZE=256)
      WRITE(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *    VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *    STR1,STR2,DSTR1,DSTR2
      CLOSE(UNIT=15)
      GOTO 10
      STOP
      END
```

FORTRAN IV   Storage Map for Program Unit THOMO

Local Variables, .PSECT $DATA, Size = 002702 (737. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
AA	L*1	002454	CH1L	R*4	002456	CH1LO	R*4	002614
CH1U	R*4	002462	CH1UO	R*4	002610	CH2L	R*4	002466
CH2LO	R*4	002624	CH2U	R*4	002472	CH2UO	R*4	002620
DR	R*4	002540	DSTR1	R*4	002646	DSTR2	R*4	002652
DT	R*4	002506	EFAK	R*4	002550	EPHEL1	R*4	002554

EPHEL2	R*4	002560	ERR	R*4	002522	HVOL	R*4	002630
J	I*2	002512	MAXE	I*2	002514	N	I*2	002526
NTAB	I*2	002634	PEDTIM	R*4	002544	RS	L*1	002441
STR1	R*4	002636	STR2	R*4	002642	TFAK1	R*4	002600
TFAK2	R*4	002604	TMAX	R*4	002502	TMIN	R*4	002476
TRANS1	R*4	002564	TRANS2	R*4	002570	US	L*1	002442
VOL	R*4	002574	XX	R*4	002516	YY	R*4	002530
ZZ	R*4	002534						

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----		Dimensions
DA	L*1	$DATA	002420	000011 (	5.)	(9)
GAIN	R*4	$DATA	000060	000060 (	24.)	(12)
N1	I*2	$DATA	001600	000144 (	50.)	(50)
N10	I*2	$DATA	001744	000144 (	50.)	(50)
N2	I*2	$DATA	002110	000144 (	50.)	(50)
N20	I*2	$DATA	002254	000144 (	50.)	(50)
PED	R*4	$DATA	000000	000060 (	24.)	(12)
R	R*4	$DATA	000760	000310 (	100.)	(50)
RO	R*4	$DATA	001270	000310 (	100.)	(50)
TEMP	R*4	$DATA	000140	000310 (	100.)	(50)
TEMPO	R*4	$DATA	000450	000310 (	100.)	(50)
TI	L*1	$DATA	002431	000010 (	4.)	(8)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
DATE	R*4	FLOAT	R*4	IFIX	I*2	ROMINT	R*4	SQRT	R*4
TIME	R*4								

FORTRAN IV   V02.5-2   Wed 22-Jun-83 10:19:00

```
0001            FUNCTION F(BL,T)
0002            X=BL/694.3
0003            A=255.5/T
0004            C=A/3.141592654
0005            C=SQRT(C)
0006            C=C*(1-15./16./A+345./512./A**2)
0007            F=(X**2+1.)/2./X
0008            F=-(SQRT(F)-1.)*2.*A
0009            F=EXP(F)/X**3/SQRT(X**2+1.)
0010            F=F*C/694.3
        C       KVANTE-EFFEKTIVITET
        C       F=F*(24.95-BL*29.3E-3)/100.
0011            END
```

FORTRAN IV   Storage Map for Program Unit F

Local Variables, .PSECT $DATA, Size = 000034 (14. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
A	R*4	000014	BL	R*4 @ 000000		C	R*4	000020
F	R*4	000004 Eqv	T	R*4 @ 000002		X	R*4	000010

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
EXP	R*4	SQRT	R*4						

FORTRAN IV   V02.5-2   Wed 22-Jun-83 10:19:12

```
0001          SUBROUTINE ROMINT(VAL,ERR,EPS,A,B,N,MAXE,TE)
0002          REAL RM(16)
0003          T=(B-A)*(F(A,TE)+F(B,TE))*.5
0004          RM(1)=(B-A)*F((A+B)*.5,TE)
0005          N=2
0006          R=4.
0007          DO 11 K=1,MAXE
0008          BB=(R*.5-1.)/(R-1.)
0009          T=RM(1)+BB*(T-RM(1))
0010          N=2*N
0011          S=0.
0012          H=(B-A)/FLOAT(N)
0013          IF(N-32) 1,1,2
0014    1     NO=N
0015          GOTO 3
0016    2     NO=32
0017    3     IF(N-512) 4,4,5
0018    4     N1=N
0019          GOTO 6
0020    5     N1=512
0021    6     DO 9 K2=1,N,512
0022          S1=0.
0023          KK=K2+N1-1
0024          DO 8 K1=K2,KK,32
0025          SO=.0
0026          KKK=K1+NO-1
0027          DO 7 KO=K1,KKK,2
0028          SO=SO+F(A+FLOAT(KO)*H,TE)
0029    7     CONTINUE
0030          S1=SO+S1
0031    8     CONTINUE
0032          S=S+S1
0033    9     CONTINUE
0034          RM(K+1)=2.*H*S
0035          R=4.
0036          DO 10 J=1,K
0037          L=K+1-J
0038          RM(L)=RM(L+1)+(RM(L+1)-RM(L))/(R-1.)
```

```
0039              R=4.*R
0040    10        CONTINUE
0041              ERR=ABS(T-RM(1))*.5
0042              VAL=(T+RM(1))*.5
0043          IF(VAL.EQ.0) VAL=1.E-8
0045              IF((ABS(ERR/VAL))-EPS) 12,12,11
0046    11        CONTINUE
0047              K=0
0048    12        VAL=(T+RM(1))*.5
0049              N=N+1
0050              MAXE=K
0051              RETURN
0052              END
```

FORTRAN IV   Storage Map for Program Unit ROMINT

Local Variables, .PSECT $DATA, Size = 000226 (75. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
A	R*4 @	000006	B	R*4 @	000010	BB	R*4	000134
EPS	R*4 @	000004	ERR	R*4 @	000002	H	R*4	000144
J	I*2	000176	K	I*2	000132	KK	I*2	000162
KKK	I*2	000172	K0	I*2	000174	K1	I*2	000164
K2	I*2	000154	L	I*2	000200	MAXE	I*2 @	000014
N	I*2 @	000012	N0	I*2	000150	N1	I*2	000152
R	R*4	000126	S	R*4	000140	S0	R*4	000166
S1	R*4	000156	T	R*4	000122	TE	R*4 @	000016
VAL	R*4 @	000000						

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size----	Dimensions
RM	R*4	$DATA	000020	000100 (32.)	(16)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
ABS	R*4	F	R*4	FLOAT	R*4				

APPENDIX E

Programs THOM1, THOM2 and THOM3

This appendix contains listings of the programs THOM1, THOM2 and THOM3. These programs are used to operate on the data file THOMSO.DAT.

THOM1 creates a new version of THOMSO.DAT from scratch, and THOM2 is easily adjusted to do single value editing on the data file. THOM3 gives a listing of the present values in the file.

```
        VO2.5-2    Wed 22-Jun-83 10:19:39

        PROGRAM THOM1
        REAL PED(12),GAIN(12),TEMP(50),R(50)
        INTEGER N1(50),N2(50)
        OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *    RECORDSIZE=256)
        READ(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *      VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *      STR1,STR2,DSTR1,DSTR2,DEFAC
        CLOSE(UNIT=15)
        DO 10 J=1,12
        PED(J)=10
        GAIN(J)=.47
        PEDTIM=80.
        EFAK=.0087
        EPHEL1=6.29E-1
        EPHEL2=4.66E-1
        TRANS1=472.E3
        TRANS2=387.E3
        VOL=.0832
        TFAK1=13.2374
        TFAK2=1.1346
        CH1U=692.
        CH1L=684.
        CH2U=682.
        CH2L=658.
        HVOL=1900.
        NTAB=50
        STR1=1.300E7
        STR2=1.015E7
        DSTR1=3.27E6
        DSTR2=1.71E6
        DEFAC=.065
        DO 20 J=1,NTAB
        TEMP(J)=0.
        R(J)=0.
```

```
C       N1(J)=0
C20     N2(J)=0
        OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *     RECORDSIZE=256)
        WRITE(15'1)  PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *       VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *       STR1,STR2,DSTR1,DSTR2,DEFAC
        CLOSE(UNIT=15)
        END
```

FORTRAN IV   Storage Map for Program Unit THOM1

Local Variables, .PSECT $DATA, Size = 001406 (387. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
CH1L	R*4	001340	CH1U	R*4	001334	CH2L	R*4	001350
CH2U	R*4	001344	DEFAC	R*4	001402	DSTR1	R*4	001372
DSTR2	R*4	001376	EFAK	R*4	001274	EPHEL1	R*4	001300
EPHEL2	R*4	001304	HVOL	R*4	001354	NTAB	I*2	001360
PEDTIM	R*4	001270	STR1	R*4	001362	STR2	R*4	001366
TFAK1	R*4	001324	TFAK2	R*4	001330	TRANS1	R*4	001310
TRANS2	R*4	001314	VOL	R*4	001320			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----		Dimensions
GAIN	R*4	$DATA	000060	000060 (	24.)	(12)
N1	I*2	$DATA	000760	000144 (	50.)	(50)
N2	I*2	$DATA	001124	000144 (	50.)	(50)
PED	R*4	$DATA	000000	000060 (	24.)	(12)
R	R*4	$DATA	000450	000310 (	100.)	(50)
TEMP	R*4	$DATA	000140	000310 (	100.)	(50)

V02.5-2   Wed 22-Jun-83 10:20:03

```
PROGRAM THOM2
REAL EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,VOL,
 *      TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,STR1,STR2,DSTR1,DSTR2,
 *      DEFAK
REAL PED(12),GAIN(12),TEMP(50),R(50)
INTEGER N1(50),N2(50),NTAB
OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
 *      RECORDSIZE=256)
READ(15'1) PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
 *      VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
 *      STR1,STR2,DSTR1,DSTR2,DEFAK
CLOSE(UNIT=15)
STR1=0.
STR2=0.
```

```
      DSTR1=0.
      DSTR2=0.
      OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *    RECORDSIZE=256)
      WRITE(15'1)  PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *    VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *    STR1,STR2,DSTR1,DSTR2,DEFAK
      CLOSE(UNIT=15)
      END
```

FORTRAN IV   Storage Map for Program Unit THOM2

Local Variables, .PSECT $DATA, Size = 001406 (387. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
CH1L	R*4	001334	CH1U	R*4	001330	CH2L	R*4	001344
CH2U	R*4	001340	DEFAK	R*4	001374	DSTR1	R*4	001364
DSTR2	R*4	001370	EFAK	R*4	001270	EPHEL1	R*4	001274
EPHEL2	R*4	001300	HVOL	R*4	001350	NTAB	I*2	001400
PEDTIM	R*4	001402	STR1	R*4	001354	STR2	R*4	001360
TFAK1	R*4	001320	TFAK2	R*4	001324	TRANS1	R*4	001304
TRANS2	R*4	001310	VOL	R*4	001314			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----		Dimensions
GAIN	R*4	$DATA	000060	000060 (	24.)	(12)
N1	I*2	$DATA	000760	000144 (	50.)	(50)
N2	I*2	$DATA	001124	000144 (	50.)	(50)
PED	R*4	$DATA	000000	000060 (	24.)	(12)
R	R*4	$DATA	000450	000310 (	100.)	(50)
TEMP	R*4	$DATA	000140	000310 (	100.)	(50)

                 V02.5-2   Wed 22-Jun-83 10:20:25

```
      PROGRAM THOM3
      REAL PED(12),GAIN(12),TEMP(50),R(50)
      INTEGER N1(50),N2(50)
      OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *    RECORDSIZE=256)
      READ(15'1)  PED,GAIN,PEDTIM,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,
     *    VOL,TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *    STR1,STR2,DSTR1,DSTR2,DEFAK
      CLOSE(UNIT=15)
      DO 10 J=1,12
      TYPE *,'CH    ,PED,GAIN : ',J-1,PED(J),GAIN(J)
      TYPE *,'PEDTIM : ',PEDTIM
      TYPE *,'EFAK : ',EFAK
      TYPE *,'EPHEL1 : ',EPHEL1
```

```
0012            TYPE *,'EPHEL2 : ',EPHEL2
0013            TYPE *,'TRANS1 : ',TRANS1
0014            TYPE *,'TRANS2 : ',TRANS2
0015            TYPE *,'VOL : ',VOL
0016            TYPE *,'TFAK1 : ',TFAK1
0017            TYPE *,'TFAK2 : ',TFAK2
0018            TYPE *,'CH1U : ',CH1U
0019            TYPE *,'CH1L : ',CH1L
0020            TYPE *,'CH2U : ',CH2U
0021            TYPE *,'CH2L : ',CH2L
0022            TYPE *,'HVOL : ',HVOL
0023            TYPE *,'NTAB : ',NTAB
0024            TYPE *,'STR1 : ',STR1
0025            TYPE *,'STR2 : ',STR2
0026            TYPE *,'DSTR1 : ',DSTR1
0027            TYPE *,'DSTR2 : ',DSTR2
0028            TYPE *,'DEFAK : ',DEFAK
0029            DO 20 J=1,NTAB
0030    20      TYPE *,'TEMP,R,N1,N2 : ',TEMP(J),R(J),N1(J),N2(J)
0031            END
```

FORTRAN IV   Storage Map for Program Unit THOM3

Local Variables, .PSECT $DATA, Size = 001426 (395. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
CH1L	R*4	001354	CH1U	R*4	001350	CH2L	R*4	001364
CH2U	R*4	001360	DEFAK	R*4	001416	DSTR1	R*4	001406
DSTR2	R*4	001412	EFAK	R*4	001310	EPHEL1	R*4	001314
EPHEL2	R*4	001320	HVOL	R*4	001370	J	I*2	001422
NTAB	I*2	001374	PEDTIM	R*4	001304	STR1	R*4	001376
STR2	R*4	001402	TFAK1	R*4	001340	TFAK2	R*4	001344
TRANS1	R*4	001324	TRANS2	R*4	001330	VOL	R*4	001334

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----		Dimensions
GAIN	R*4	$DATA	000060	000060 (	24.)	(12)
N1	I*2	$DATA	000760	000144 (	50.)	(50)
N2	I*2	$DATA	001124	000144 (	50.)	(50)
PED	R*4	$DATA	000000	000060 (	24.)	(12)
R	R*4	$DATA	000450	000310 (	100.)	(50)
TEMP	R*4	$DATA	000140	000310 (	100.)	(50)

APPENDIX F

Program THOM4

This appendix contains a listing of the THOM4 program. The program is used for calibration of the charge integrating ADC (LeCroy 2250L).

The program leads the operator through the calibration procedure of the ADC and optionally writes the new calibration constants on the data file THOMSD.DAT.

```
        VO2.5-2      Wed 22-Jun-83 10:20:51

        PROGRAM THOM4
        REAL PED(12),PEDO(12),GAIN(12),GAINO(12),TEMP(50),R(50)
        INTEGER N1(50),N2(50)
        BYTE ADATE(9),ATIME(8),TEXT(80)
        REAL SUMI(12),SUMIV(12),SUMII(12)
        DO 2 JJ=1,12
        SUMI(JJ)=0.
        SUMIV(JJ)=0.
        SUMII(JJ)=0.
        SUMV=0.
        SUMVV=0.
        N=0
        WRITE(7,100)
        FORMAT(' CALIBRATION OF LECROY 2250L',/
     *       ' APPLY TEST VOLTAGE TO FRONT INPUT AND CAMAC ''INHIBIT''',/
     *       ' ENTER NUMBER OF GATES FOR EACH TEST VOLTAGE')
        READ(5,*) NUM
        WRITE(7,101)
        FORMAT(' ENTER TEST VOLTAGE ((0 FOR CONTINUE)')
        READ(5,*) V
        IF(V.LT.0.) GOTO 20
        CALL CSSA(9,512*4,I,IQ)
        CALL ISLEEP(0,0,0,1)
        DO 10 J=1,NUM
        N=N+1
        SUMV=SUMV+V
        SUMVV=SUMVV+V**2
        CALL CSSA(25,512*4,I,IQ)
        CALL ISLEEP(0,0,0,1)
        DO 10 JJ=1,12
        CALL CSSA(2,512*4+32*(JJ-1),I,IQ)
        IF(IQ.NE.0) GOTO 6
        WRITE(7,*) '*** WARNING NO Q-RESPONSE - TRY AGAIN ***'
        GOTO 1
        SUMI(JJ)=SUMI(JJ)+I
        SUMIV(JJ)=SUMIV(JJ)+I*V
```

```
10      SUMII(JJ)=SUMII(JJ)+FLOAT(I)**2
        GOTO 5
20      IF(N.EQ.0) GOTO 1
        B=SUMVV-SUMV**2/N
        WRITE(7,102)
102     FORMAT('0',X,
     *     'CHANNEL          SLOPE     PEDESTRAL',
     *     '    CORRELATION      CONVERSION FACTOR',/,
     *     '              [cnts/Volt]        [cnts]',
     *     '                        [pC/cnt]')
        IF(B.EQ.0.) GOTO 1
        DO 25 JJ=1,12
        J=JJ
        A1=(SUMIV(J)-SUMV*SUMI(J)/N)/B
        A0=(SUMI(J)-A1*SUMV)/N
        PED(J)=A0
        GAIN(J)=12.5/(A1+1.E-8)
        C=SUMII(J)-SUMI(J)**2/N
        RR=9999.999
        IF(C.NE.0.) RR=(SUMIV(J)-SUMV*SUMI(J)/N)**2/C/B
25      WRITE(7,103) J-1,A1,A0,RR,12.5/(A1+1.E-8)
103     FORMAT(X,I6,F15.2,F13.2,F15.3,F15.3)
        WRITE(7,109) NUM,N/NUM
        WRITE(7,*) 'TO STORE RESULTS ON "THOMSO.DAT" TYPE "Y"'
        READ(5,104) AA
        IF(AA.NE.'Y') GOTO 79
        OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='OLD',ACCESS='DIRECT',
     *     RECORDSIZE=256)
        READ(15'1) PEDO,GAINO,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,VOL,
     *     TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *     STR1,STR2,DSTR1,DSTR2
        CLOSE(UNIT=15)
        OPEN(UNIT=15,NAME='THOMSO.DAT',TYPE='NEW',ACCESS='DIRECT',
     *     RECORDSIZE=256)
        WRITE(15'1) PED,GAIN,EFAK,EPHEL1,EPHEL2,TRANS1,TRANS2,VOL,
     *     TFAK1,TFAK2,CH1U,CH1L,CH2U,CH2L,HVOL,NTAB,TEMP,N1,N2,R,
     *     STR1,STR2,DSTR1,DSTR2
        CLOSE(UNIT=15)
79      WRITE(7,*) 'FOR PRINTOUT OF RESULTS TYPE "Y"'
        READ(5,104) AA
104     FORMAT(A)
        IF(AA.NE.'Y') GOTO 1
        CALL DATE(ADATE)
        CALL TIME(ATIME)
        WRITE(6,110) ADATE,ATIME
110     FORMAT(X,9A,T80,8A,//,T10,
     *     ' CALIBRATION OF LECROY MODULE 2250L',
     *     //,T10,' INTERNAL GATE (APPROX 80. NSEC) IS USED WITH',/,
     *     T10,' CAMAC ''INHIBIT'' AND TEST',
     *     ' VOLTAGE ON FRONT PANNEL INPUT')
        WRITE(6,122)
122     FORMAT('0',X,T10,
     *     ' CHANNEL          SLOPE     PEDESTRAL',
```

```
*      ,      CORRELATION      CONVERSION FACTOR',/,T10,
*      ,            [cnts/Volt]          [cnts]',
*      ,                          [pC/cnt]')
       DO 45 JJ=1,12
       J=JJ
       A1=(SUMIV(J)-SUMV*SUMI(J)/N)/B
       AO=(SUMI(J)-A1*SUMV)/N
       C=SUMII(J)-SUMI(J)**2/N
       RR=9999.999
       IF(C.NE.O.) RR=(SUMIV(J)-SUMV*SUMI(J)/N)**2/C/B
       WRITE(6,123) J-1,A1,AO,RR,12.5/A1
       FORMAT(X,T10,I6,F15.2,F13.2,F15.3,F15.3)
       WRITE(6,109) NUM,N/NUM
       FORMAT('O',T10,I4,' TEST GATES AT EACH OF'
*      ,I4,' VOLTAGE SETTINGS',/,'O')
       WRITE(7,111)
       FORMAT(' ENTER TEXT FOR PRINTOUT (80A)')
       READ(5,112) TEXT
       FORMAT(80A)
       IF(TEXT(1).EQ.32.AND.TEXT(2).EQ.32) GOTO 60
       WRITE(6,113) TEXT
       FORMAT(X,T10,80A)
       GOTO 55
       CLOSE(UNIT=6)
       GOTO 1
       END
```

FORTRAN IV   Storage Map for Program Unit THOM4

Local Variables, .PSECT $DATA, Size = 002272 (605. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
AA	R*4	002102	AO	R*4	002066	A1	R*4	002062
B	R*4	002056	C	R*4	002072	CH1L	R*4	002152
CH1U	R*4	002146	CH2L	R*4	002162	CH2U	R*4	002156
DSTR1	R*4	002204	DSTR2	R*4	002210	EFAK	R*4	002106
EPHEL1	R*4	002112	EPHEL2	R*4	002116	HVOL	R*4	002166
I	I*2	002050	IQ	I*2	002052	J	I*2	002054
JJ	I*2	002026	N	I*2	002040	NTAB	I*2	002172
NUM	I*2	002042	RR	R*4	002076	STR1	R*4	002174
STR2	R*4	002200	SUMV	R*4	002030	SUMVV	R*4	002034
TFAK1	R*4	002136	TFAK2	R*4	002142	TRANS1	R*4	002122
TRANS2	R*4	002126	V	R*4	002044	VOL	R*4	002132

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----		Dimensions
ADATE	L*1	$DATA	001430	000011 (	5.)	(9)
ATIME	L*1	$DATA	001441	000010 (	4.)	(8)
GAIN	R*4	$DATA	000140	000060 (	24.)	(12)
GAINO	R*4	$DATA	000220	000060 (	24.)	(12)

```
N1      I*2     $DATA   001120  000144 (    50.)  (50)
N2      I*2     $DATA   001264  000144 (    50.)  (50)
PED     R*4     $DATA   000000  000060 (    24.)  (12)
PEDO    R*4     $DATA   000060  000060 (    24.)  (12)
R       R*4     $DATA   000610  000310 (   100.)  (50)
SUMI    R*4     $DATA   001572  000060 (    24.)  (12)
SUMII   R*4     $DATA   001732  000060 (    24.)  (12)
SUMIV   R*4     $DATA   001652  000060 (    24.)  (12)
TEMP    R*4     $DATA   000300  000310 (   100.)  (50)
TEXT    L*1     $DATA   001451  000120 (    40.)  (80)
```

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
CSSA	R*4	DATE	R*4	FLOAT	R*4	ISLEEP	I*2	TIME	R*4

APPENDIX G

Subroutine ADC12

This appendix contains a listing of the subroutine ADC12. The subroutine is linked to the MASTER program and called twice by the routine GEM for initialization and data readout of the charge integrating ADC (LeCroy 2250L).

In the call of ADC12, N=1 for initialization and N=2 for data readout. ILAS is the array which should receive the data.

```
           V02.5-2     Wed 22-Jun-83 18:22:16

       SUBROUTINE ADC12(N,ILAS)
       BYTE TEST
       INTEGER IDAT(12,4),ILAS(6,4)
       GOTO(10,20) N
       CALL CSSA(9,4*512,I,IQ)
       RETURN
       DO 30 JJ=1,4
       DO 30 J=1,12
       IDAT(J,JJ)=0
       II=1
       III=0
       CALL CSSA(0,4*512+11*32,I,IQ)
       IF(IQ.NE.0) GOTO 50
       IF(II.EQ.1.OR.II.EQ.3) GOTO 80
       TYPE *,'*** WARNING - MISSING TRIGGER'
       GOTO 80
       III=III+1
       DO 60 J=0,11
       JJ=J
       CALL CSSA(2,4*512+J*32,IDAT(JJ+1,II),IQ)
       IF(IQ.EQ.0) TYPE *,'*** WARNING -- NO Q RESPONSE'
     *      ' FROM CHANNEL ',JJ,' ***'
       CONTINUE
       IF((II.EQ.1.OR.II.EQ.3).AND.IDAT(1,II).LT.20) GOTO 40
       IF(II.EQ.2.OR.II.EQ.4) GOTO 70
       II=II+1
       GOTO 40
       IF(II.EQ.4) GOTO 80
       II=3
       GOTO 40
       DO 90 JJ=1,4
       DO 90 J=1,4
       ILAS(J,JJ)=IDAT(J,JJ)
       IF(III.EQ.0) GOTO 99
       WRITE(7,*) 'RAW THOMSON DATA:'
```

```
      WRITE(7,*) 'LASERMONITOR      :',(ILAS(1,JJ),JJ=1,III)
      WRITE(7,*) 'CHANNEL   1       :',(ILAS(2,JJ),JJ=1,III)
      WRITE(7,*) 'CHANNEL   2       :',(ILAS(4,JJ),JJ=1,III)
      WRITE(7,*) 'GATE WIDTH        :',(ILAS(5,JJ),JJ=1,III)
      WRITE(7,*) 'TIME OF SHOT      :',(ILAS(6,JJ),JJ=1,III)
      WRITE(7,*) 'NUMBER OF GATES :',III
      WRITE(7,*) ' '
      RETURN
      IF(III.EQ.0) WRITE(7,110)
      FORMAT(' THOMSON DATA:',
     *    /,'   NUMBER OF GATES:',I3,
     *    /,4(3X,4I5:/))
      FORMAT(' NO THOMSON DATA ON THIS SHOT')
      END
```

FORTRAN IV   Storage Map for Program Unit ADC12

Local Variables, .PSECT $DATA, Size = 000202 (65. words)

Name	Type	Offset	Name	Type	Offset	Name	Type	Offset
I	I*2	000162	II	I*2	000172	III	I*2	000174
IQ	I*2	000164	J	I*2	000170	JJ	I*2	000166
N	I*2 @ 000000		TEST	L*1	000160			

Local and COMMON Arrays:

Name	Type	Section	Offset	------Size-----	Dimensions
IDAT	I*2 Vec	$DATA	000004	000140 (48.)	(12,4)
ILAS	I*2 Vec@	$DATA	000002	000060 (24.)	(6,4)

Subroutines, Functions, Statement and Processor-Defined Functions:

Name	Type	Name	Type	Name	Type	Name	Type	Name	Type
CSSA	R*4								

APPENDIX H

Gate Pulse Trigger

This appendix shortly describes the function of the Gate Pulse
Trigger module (P 1358). It also includes a circuit drawing.

The module respons to two CAMAC functions.

F1A15 reads a preset module identification from a DIP switch.
This function is not so interesting from the experimentalists
point of view.

F16AO flashes 4 LEDs according to the bits 0, 1, 2 and 3 of the
data word. It also generates a Gain OUT pulse for photomultiplier
gating and a trigger for the Gate Pulse Generator (G.P.G.OUT).
If the LEDS are mounted inside the spectrometer close to the in-
put slit, this allows you to check the sensitivity of the data
acquisition system. F16AO with bit 4 set in the data word genera-
tes a Test OUT pulse suited for a laser diode to trigger the ruby
laser energy monitor. This also gives a Gain OUT pulse for the
photomultipliers but does not generate a trigger on G.P.G.OUT.
Using this function you can check the triggering system right
from the laser energy monitor.

The Sync IN input should receive a sync pulse from the ruby
laser. The module then produces a Gain OUT pulse after a preset
delay.

The 90 V OUT is designed for energizing a laser energy monitor
diode.

The output from the laser energy monitor is fed into the Monitor
IN input. Here the signal is divided by a resistive network into
the outputs C.F.D.OUT for the Constant Fraction Discriminator and

ADC OUR for the charge integrating ADC. The signal from the Constant Fraction Discriminator is connected to C.F.D.IN where the polarity is inverted before it appears on G.P.G.OUT for the Gate Pulse Generator.

The features of Sync IN, Gain OUT, Test OUT, LED OUT and 90 V OUT have not been incorporated into the present design of the diagnostic.
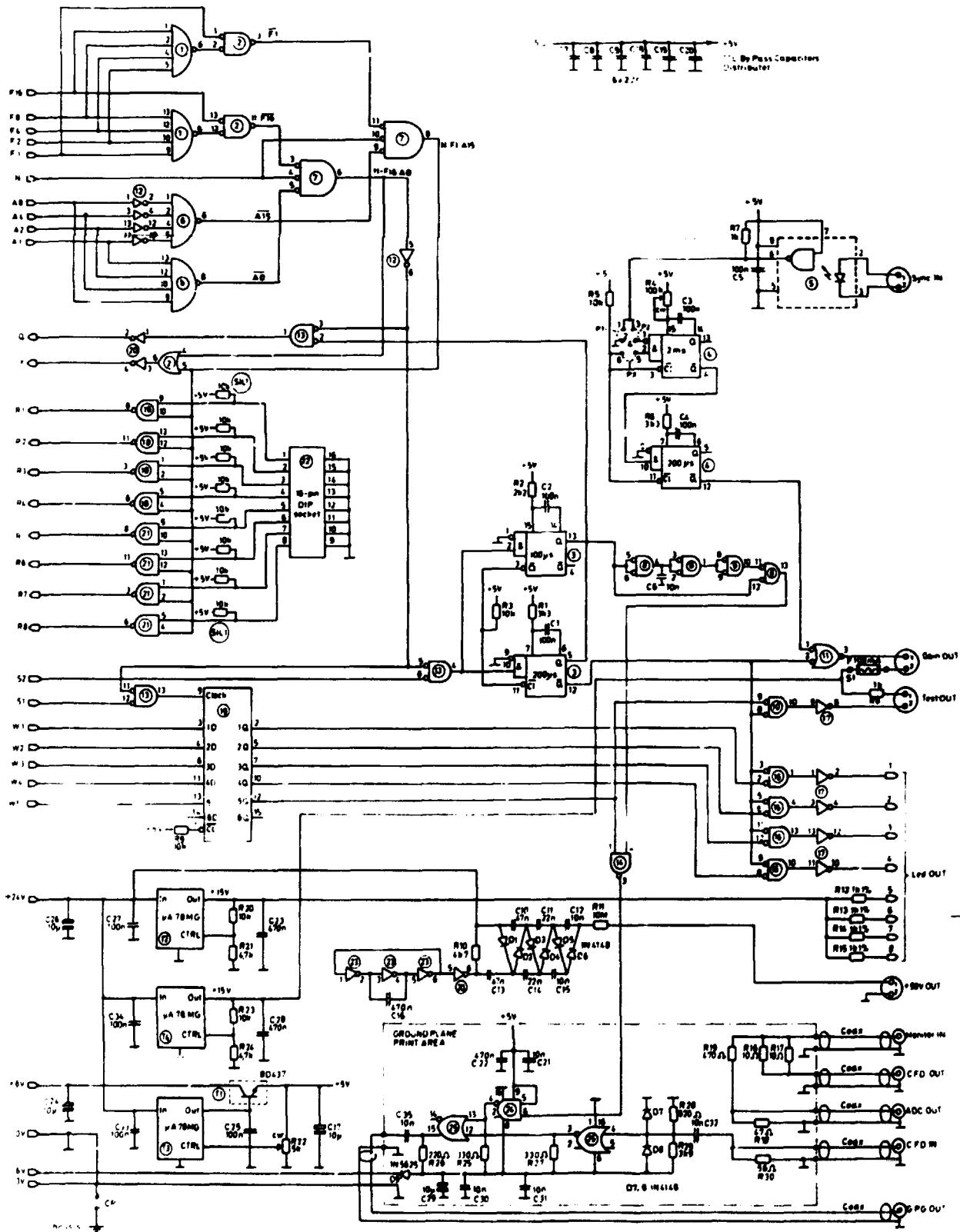
Fig. H-1. Diagram of Gate Pulse Trigger module.

INDEX

Risø - M - 2397

Title and author(s)	Date August 1983
The Thomson Scattering system at DANTE M. Gadeberg	**Department or group** Physics Dept.
	Group's own registration number(s)

70 pages + tables + illustrations

Abstract

This report describes the construction and operation of the 90 deg Thomson Scattering diagnostic at DANTE. The system is based on a double-pulse ruby laser and a three channel soectrometer. Two single point measurements can be made during each plasma discharge.

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