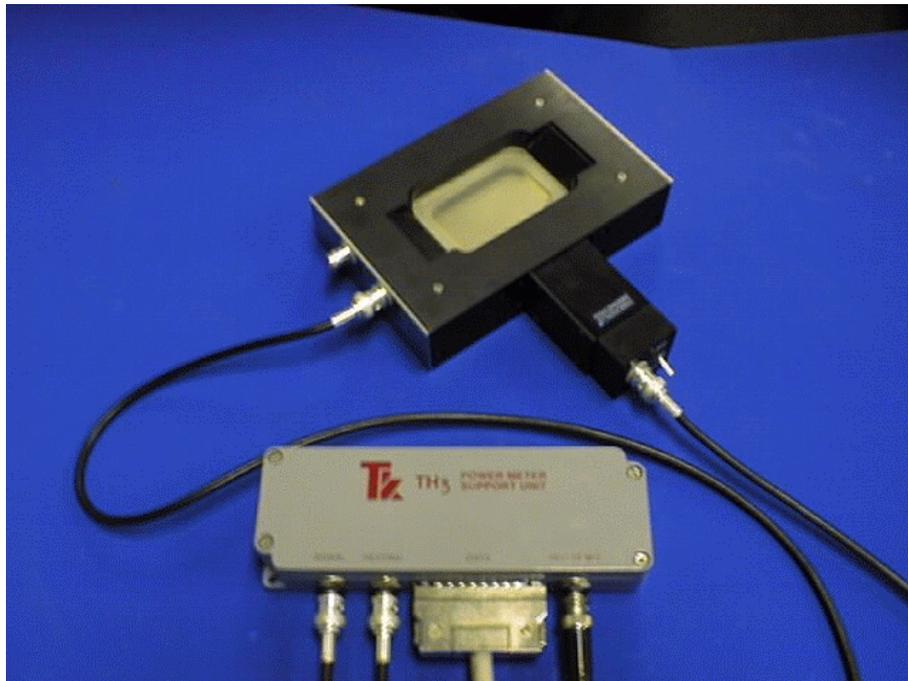


**Installation and Operating Instructions for the TK TeraHertz  
Absolute Power Meter System  
Version 2  
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## INTRODUCTION

**The TK TeraHertz Absolute Power Meter System** is an autocalibrating power meter for use with free-space beams in the frequency range from 30GHz to 3THz.

The sensitive area of the System is greater than 30mm in diameter.

**The System** has a typical NEP of about  $5\mu\text{W Hz}^{-1/2}$ .

**Software** features include:

- i) Autocalibration
- ii) Frequency dependent window-loss correction, and
- iii) A full set of routines which trap equipment and operator errors.

**The System** comprises two parts:

- i) **The Head** and
- ii) **The Support Unit.**

**The Head** is a photo-acoustic detector using a closed air-cell and a pressure transducer. Calibration is provided by ohmic heating of a thin metal film within the cell.

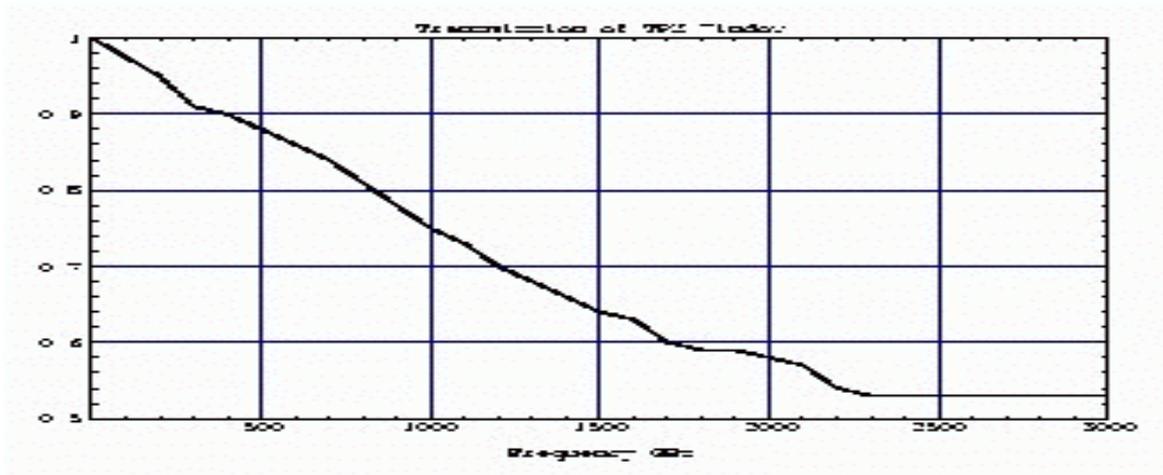
**The Support Unit** is based around a National Instruments 12 Bit PCI based A/D Card, the PCI-6023E. Additional electronics have been added to provide an external Lock-In Amplifier (LIA), to provide film heating for calibration, and amplify the signal from the Head's microphone pressure sensor. The compiled software, written in LabVIEW controls the operation of the LIA and displays the microwave power.

## PRINCIPLES OF OPERATION

**The TeraHertz Power Meter System** measures power in a beam directed into the Head window. The Head comprises a closed air-filled cell formed by two closely-spaced parallel windows with a thin metal film in the gap between them. A known fraction (close to 50%) of the power of the incident beam is absorbed in the metal film, the remainder being partly transmitted through the cell and partly reflected from it.

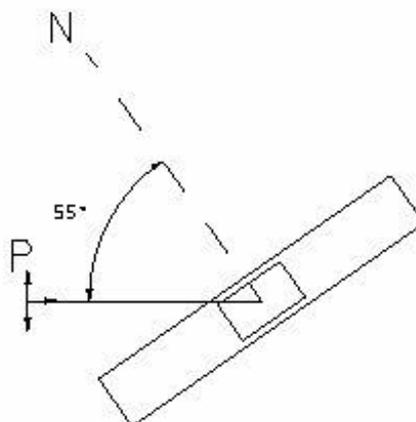
The beam is to be 100% amplitude-modulated either at its source or by a chopper placed in the path of the beam. The modulation frequency is to be in the range 10Hz to 50Hz. The absorption of the power in the film produces modulated variations in the temperature of the film and of the layers of air in contact with the film. In turn this produces a modulation of the pressure in the cell which is detected by a pressure-transducer, measured by the LIA and displayed on the PC. The modulated pressure change is closely proportional to the total absorbed power; it depends negligibly on the distribution of the absorbed power over the film.

To calibrate the Power Meter, a measured amount of modulated ohmic power is generated in the film. The Support Unit does this by passing a modulated current through it via electrodes which contact opposite edges of the film. A look-up table in the software gives the window-loss as a function of frequency and fractional film absorption, based upon TK's laboratory measurements, shown below in figure 1.



**Figure 1.** Transmission of TPX Window

There are no reflections from the windows if the Power Meter Head is set so that the beam is incident at the Brewster angle with the plane of polarisation in the plane of incidence, as shown in Figure 2 below.



P Polarization vector (E-field)

N Normal to Window

**Figure 2.** Use of Power Meter at Brewster Angle.

The heating circuit performs the calibration automatically to determine the external responsivity each time the System is switched on.

## INSTALLATION

### Deliverable items

In addition to the Power Meter Head (which may have been purchased separately) and these instructions, you should have received the following components:

1. National Instruments PCI-6023E PCI based A/D card,
2. 68 pin M-F SCSI III cable,
3. Preamp and film heating box,
4. Two BNC cables,
5. CD-ROM containing NI-DAQ 6.5 software,
6. CR-ROM containing compiled Power Meter program.

### PC requirements

The NI card is to be installed in an IBM PC or compatible with a spare full height card PCI slot and a CD-ROM drive. Windows 95, 98 or Windows NT should be installed as the operating system.

If the user is inexperienced in installing cards and configuring PC's, it may be useful to obtain advice locally. If this is not available, Thomas Keating Ltd would be pleased to advise.

### Installing NI-DAQ software

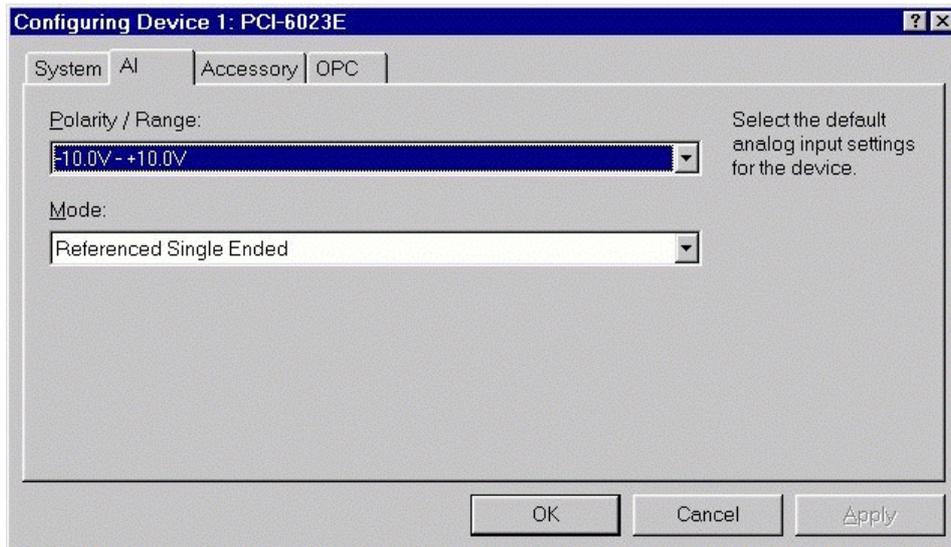
National Instruments' NI-DAQ software is on an Autorun CD-ROM supplied with the board and provides the interface between the A/D hardware and the compiled LabVIEW Power Meter Application. Read and follow the instructions supplied with the NI-DAQ board and CD-ROM.

**\* Before installing the board into your PC you must first install the NI-DAQ 6.5 software, following the instructions provided on the Autorun CD.**

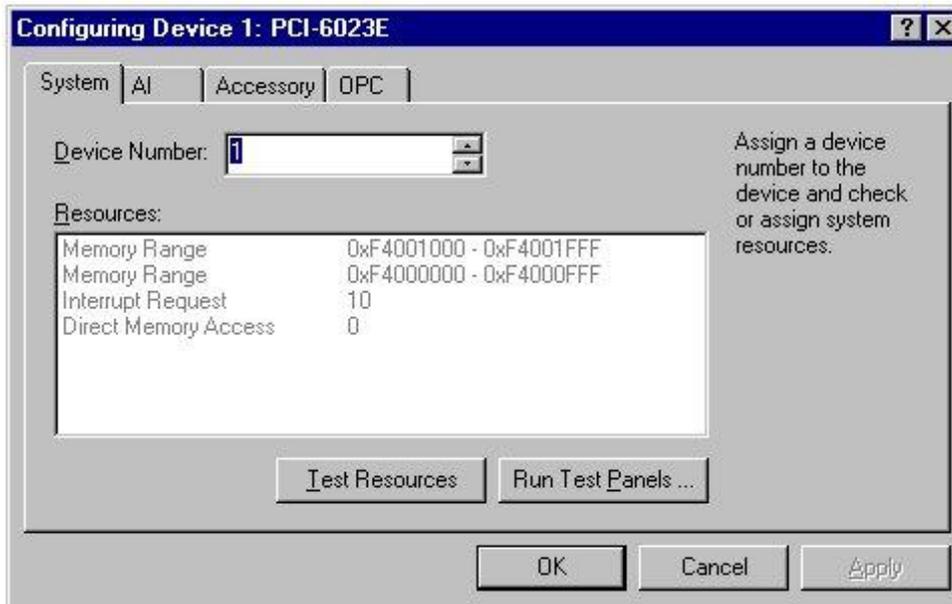
You may care to install the manuals for the PCI-6023E at this point.

### Mechanical installation of NI A/D Card

- Install the PCI-6023E card in a vacant PCI slot and reboot the PC.
- Go into Windows Explorer > Measurement and Automation > Devices and Interfaces. You should see the installed card.
- Use the right hand button on your Mouse to bring up the Properties section and select for AI section.



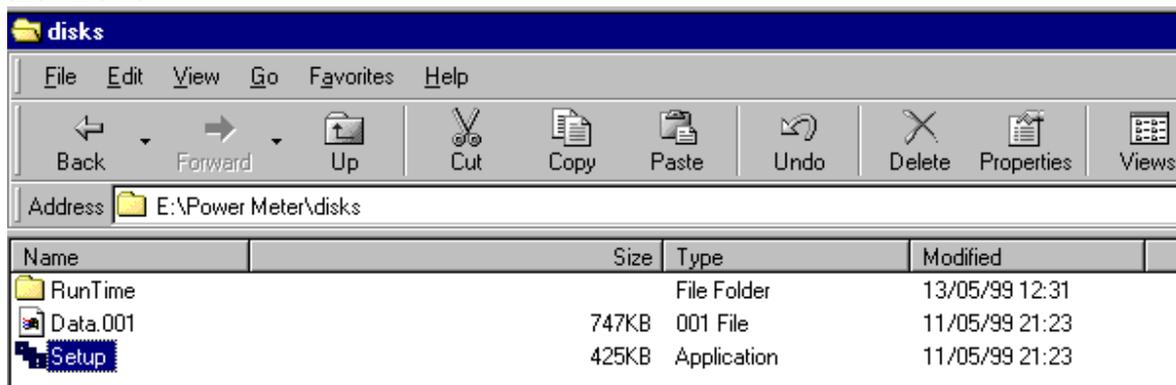
- Set the mode to **Reference Single Ended** and exit.
- Note the **device number** for the PCI-6023E (shown in the top left hand corner of the window). Unless there are other DAQ based cards installed, this should be board #1.
- You must also check that the board has been assigned a **Direct Memory Access (DMA)** channel. Select the System tab and the display should be as shown below. If this is not set there may be interference with the Power Meter operation from other processes taking place on the PC. Ensuring the running of DMA can be specific to the PC you are running. If you have problems you should refer to the operation manual of your PC or contact us. However, here are our suggestions of what to try should you have any problems.
  - To achieve this it may be necessary to set the Plug & Play option in the PC's BIOS to Yes before installing the card.
  - If this fails it may be necessary to remove all PCI cards and other cards which may be causing a conflict and install the PCI-6023E card first before replacing the cards.



## Installing the Power Meter Software

The Power Meter Software is included on the TK Power Meter CD-ROM supplied with the Support Unit.

- Access the TK Power Meter CD-ROM and run SETUP from the directory \Power Meter\disks as shown below



- Follow the on screen Installation instructions as shown
- Once the software is installed you must REBOOT your PC as instructed for the installation to be completed

The CD-ROM also contains a copy of this manual (TK Power Meter Manual.doc) as a Word97 document. You may care to copy this to your Power Meter directory at this point.

- The Power Meter Setup will create a Program Folder for the Power Meter Software. We also suggest placing a shortcut of the main program (Tk\_pm.exe) on your desktop, which should look like



## Connecting Power Meter cables



- Connect the SCSI III 68 pin cable from the PCI card to the Preamp/Film heating box socket labelled **DATA**. Ensure that a complete connection is made, with the side connector clips properly in place.
- Connect the source of modulation (chopper or electrical) to the BNC connector labelled **REFERENCE**.
  - The Reference voltage should be TTL, that is square wave 0V to +5V. The LIA will work with lower voltages but is unable to lock into signals less than 1V. If there is a Time Out error when the software goes through the calibration cycle, one check you should make is the level of the reference voltage.

- Using one of the BNC cables supplied, connect the pressure transducer BNC output on the top of the Power Meter Head to the BNC connector labelled **SIGNAL**. The second cable should run from one of the two film heating connections on the side of the Power Meter to the BNC cable labelled **HEATING**.

### Checking the Power Meter's Film Resistance

- Measure and note down the Head's film resistance,  $R_f$  with a Digital Resistance meter. The resistance should not differ from the value supplied or previously measured by more than 5%<sup>1</sup>. If the variation is greater than this, Thomas Keating Ltd. should be contacted.

## OPERATION

To avoid damaging the metal film in the Head, CW beam power, spread over the 30mm window aperture, should not exceed 500mW. If the beam power is to be concentrated in an area significantly smaller than the aperture, this beam power limit should be correspondingly reduced to avoid local damage of the film.

The maximum power that can be measured without reaching Full Scale Deflection is 200mW. If you wish to measure power higher than this, contact Thomas Keating for advice.

### Positioning the Power Meter Head

The Power Meter measures only the beam power incident *within its window aperture* and it should be placed in the beam where the beam-width is small enough to be clearly accommodated within that aperture. This may require the use of a lens or mirror to condense the beam to a beam-waist at the Power Meter Head.

To make power measurements which are free of frequency-dependent calibration errors caused by reflections from the windows, the Power Meter Head should be used at the Brewster setting to the beam: That is to say the angle between the beam axis and the normal to the window should be  $55.5 \pm 5^\circ$ . The polarisation of the beam must also be in the plane of incidence (see figure 2). If the E-field of the beam is in the horizontal plane the meter can simply stand on its base; otherwise an appropriate support wedge for the meter will be required. If the beam is not linearly polarised it is necessary to use a wire-grid polariser in the beam and measure separately the power in the two orthogonal linearly-polarised signals.

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<sup>1</sup>. A film resistance in the range  $110\Omega$  to  $230\Omega$  is acceptable. Theoretical analysis indicates an absorptance rising from 48% when  $R_f$  is  $110\Omega$  to 50% at  $160\Omega$  and returning to 48% for  $230\Omega$ ; measurements on such films confirms an absorptance of  $49 \pm 1.5\%$  though the submillimetre range.

## Signal-beam Modulation

The signal beam must be amplitude-modulated. Ideally this modulation should be square-wave as the calibration process is based upon a square-wave modulation. The frequency should be in the range 10Hz to 50Hz, and the lowest NEP is found in the middle of this range.

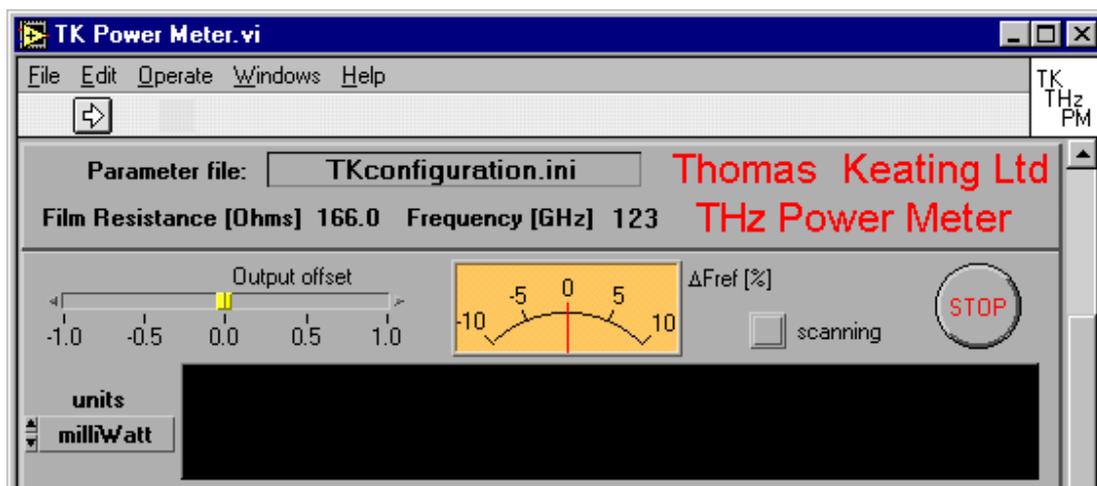
If the source of the beam can be switched on and off electrically within about 1mS, good square-wave modulation at 10-50Hz can be produced at source. If the source cannot be modulated in this way, a mechanical modulator in the form of a rotating bladed shutter (a “chopper”) should be placed in the beam path. To approximate square-wave modulation the width of each blade in the chopper would have to be much larger than the width of the beam at the modulator. In practice, the need to limit the size of the modulator will result in some deviation from the ideal square-wave form. This will tend to underestimate the signal power. To assess the level of error that might be incurred, an extreme case can be considered, namely modulation of *sinusoidal* form with a peak value corresponding to the unobstructed beam (i.e. the beam power). In such a case, the Power Meter System will underestimate the beam power by 26%. In practice, of course, the modulation will usually be much closer to the pure square-wave and the error incurred very much less.

If a mechanical chopper is being used, care should be taken to insure that it does not modulate infra-red and visible light. The Head windows transmit infra-red and visible light and the Power Meter will detect any changing or modulated power at these wavelengths incident upon it. The Head will also respond to air-pressure fluctuations at the reference frequency, generated by, say, the modulator blades. To reduce false signals of these kinds it may be necessary to introduce a baffle at the modulator with an aperture in it to pass the beam. Black polyethylene across the window aperture can also be used significantly to reduce IR and visible radiation entering the Head. The reduction in signal level from the Power Meter System when a second, similar, sheet is added will provide a measure of the attenuation in the first sheet, so that a correction can be made to the displayed power to compensate for the attenuation.

## RUNNING THE SOFTWARE

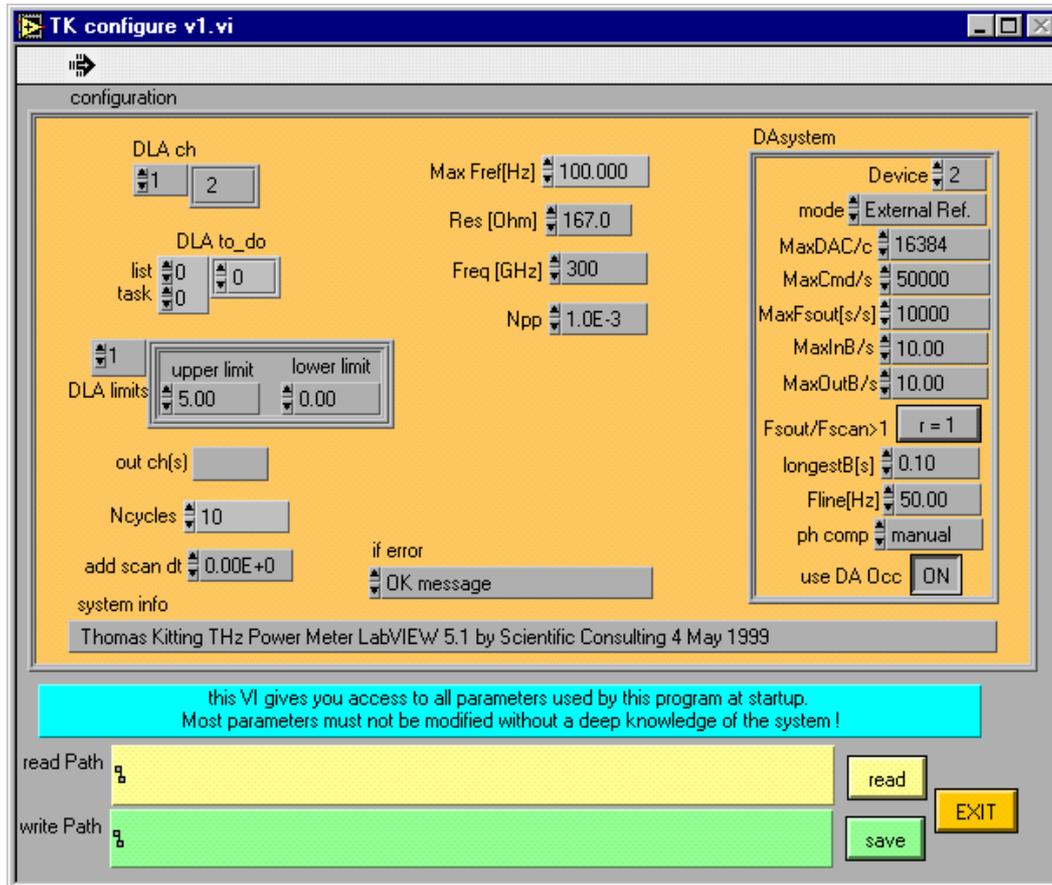
### Configuring the Software

The Power Meter software is started by double clicking on the shortcut icon which brings up the Power Meter Front panel. The top section should look like



The first time you run the software it will need configuring to select the correct device number for your PCI-6023E board.

- Delete the File name **Tkconfiguration.ini** using the cursor.
- Run the Program by clicking on the start button, , located in the top left hand corner of the TK Power Meter.vi window. You can also start the program from the menu bar using Operate > Run. The absence of the configuration file will force the program to present to you the following panel



To calibrate the software you must click on the “read” button and select **Tkconfiguration.ini**

Then adjust the following parameters on the panel:

- § The **Device #** should correspond to the device number noted down from the **Devices and Interfaces** section of Windows Explorer. The above example shows a device number of 2, but stand alone applications are likely to have the value 1.
- § The **Res [Ohm]** should be set to  $R_f$ , the measured film resistance.
- § The **Freq [GHz]** set to the expected or usual frequency of the THz signal.

The values of film resistance and frequency can be changed any time the program is subsequently run without entering this configuration procedure.

When you have set these parameters, press the “save” button and save the parameters to the **Tkconfiguration.ini** file.

- Click on “EXIT” to proceed with a measurement

NOTE: You should only need to configure the software once. For subsequent running of the software you need only specify the desired configuration file (Default = Tkconfiguration.ini)



To ensure that calibration is successful it may be necessary to repeat the procedures under *Configuring the Software*, but the stability of the modulation REFERENCE signal should also be checked.

After calibration the screen displays the Power detected by the Head, adjusted for Window loss at the specified signal frequency. Film resistance and THz frequency are displayed in the top panel, along with the name of the initialisation file. Small deviations of the reference frequency away from that used at calibration time are displayed as  $\Delta F_{ref}[\%]$ . A yellow indicator labelled **scanning** indicates that measurements are taking place.

A chart at the bottom tracks power levels as a function of time.

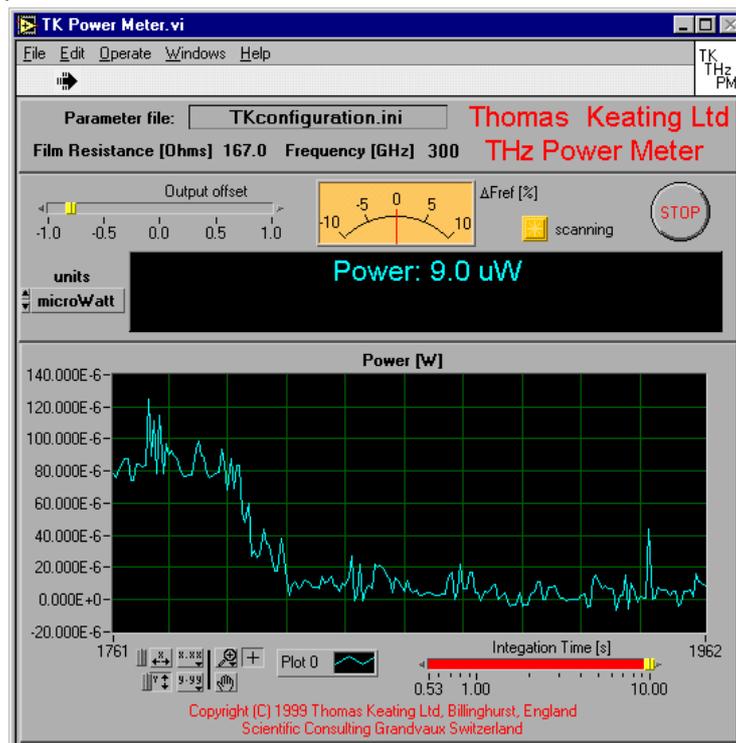
The user is presented with a number of controls to adjust the performance of the Instrument:

- The **STOP** button halts the program.

When the measurement is halted, the program asks if you want to save the data to a spreadsheet file. This will produce a text file of the chart history including the film resistance, frequency of measurement and power versus time data. This can be useful in checking power stability over time.

- The **output offset** allows the reading to be adjusted to zero.

When making a measurement with the Power Meter there may be a small offset signal present. This can be corrected for using the Output offset control. An example of how the signal is zeroed in this way is shown below.

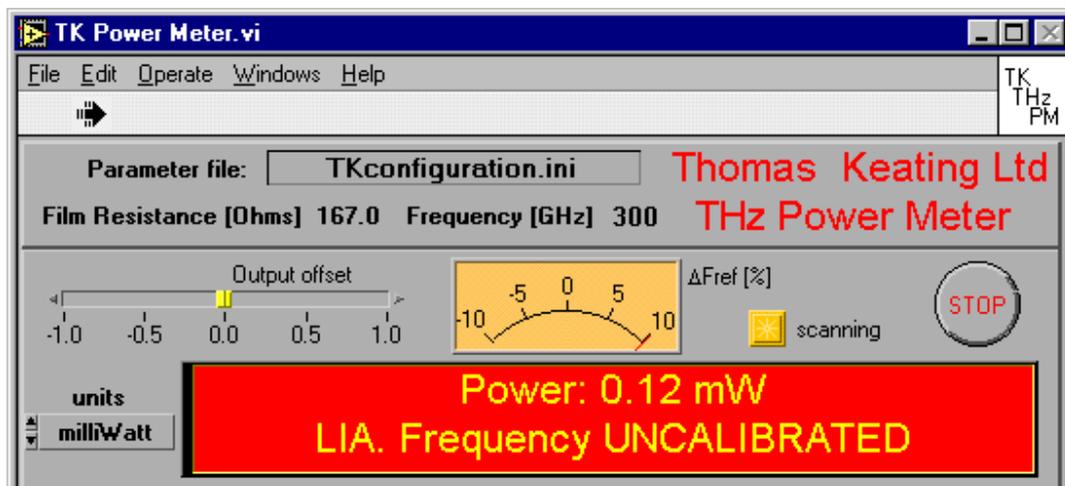


- The **units** control allows one to change the display from milliWatts to microWatts.
- The **Integration Time [s]** control changes the digital integration time displayed on the meter and the chart. The software performs a decaying average on the train of measurement values. Increasing the **Integration time** extends the time. The default integration time is between 1s and 10s. To increase this range, simply highlight the right hand side number on the scale and type in the new value.



- Clicking the Secondary Mouse button on the chart brings up a menu enabling the user to control the appearance of the chart. These settings can also be changed using the controls below the chart.

The software also runs a full set of error trapping routines and will indicate to the user faults such as the loss of a LIA reference signal or a significant change in the modulation frequency supplied as a reference to the LIA (as shown below).



This must remain constant during a measurement session as the responsivity of the Head is dependent upon the modulation frequency. To correct this error the Power Meter must be calibrated at the new frequency or the reference frequency should be changed back to that used in the initial calibration.

## **TROUBLESHOOTING AND MAINTENANCE**

Periodic measurement, say once every six months, of the Power Meter Head's film resistance is advisable, to check that the film has not deteriorated or been damaged by excess incident beam power. The accuracy of the System is based upon a good knowledge of  $R_f$ . If the resistance changes by more than 5%, Thomas Keating Ltd should be informed. Thomas Keating Ltd should also be informed if the measured NEP, displayed by the software at the end of the calibration cycle, deteriorates significantly. Note, however, that the NEP increases as the beam frequency is increased because the window loss rises.

A 9V PP3 type battery powers the pressure transducer and lies in the top section of the Power Meter Head. The transducer draws very little current and will supply power over many weeks of full time operation. However the battery should be replaced, say, once a year. This can be done by removing the cover on the side of the top section which is held in by the four Philips type screws. Replace the battery and refix the cover.

## **ACKNOWLEDGEMENTS**

All manufacturer's trademarks are acknowledged. Thomas Keating Ltd would like to thank Prof. Derek Martin of QMW, University of London, who devised the Photo-acoustic techniques used in the Power Meter, and Dennis Moss of the UK National Physical Laboratory for advice in the design of the System. This LabView version was developed jointly by TK and Scientific Consulting, EnGourge, CH-1603 Grandvaux, Switzerland ([scientific.consulting@worldcom.ch](mailto:scientific.consulting@worldcom.ch)).