Photonetics TUNICS-PR

Tunable External Cavity Laser

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TUNICS-PR/PRI

WAVELENGTH TUNABLE
LASER DIODE SOURCE

USER'S GUIDE

3642-SU-02-G

CONTENTS

INTRODUCTION

TUNICS 1550 and TUNICS 1300 are ideal general-purpose instruments for fiber-optic system and component testing, and for research and development in the field of optical communications. They offer maximum flexibility to cover all present and future requirements for tunable laser diode sources in the laboratory.

The optical layout is a modified Littman-Metcalf configuration. The double-pass reflection on the grating provides maximum dispersion while the very short cavity made possible by the scanning mechanism maximizes mode-spacing. Mode competition is thus avoided and spectrally pure, truly single-mode operation is guaranteed. The high-performance optical isolator and the angle-polished output fiber connector also contribute to good spectral purity by protecting the laser cavity from interferences from the user's set-up.

Furthermore, the cavity in TUNICS is self-aligned, a key feature for long term stability. In most laser cavities, minute changes in the position of the optical elements, as can be caused by shocks, vibrations, temperature changes or mechanical drifts over time, can rapidly degrade both the power and the spectral purity. In contrast, the rear reflector in the TUNICS cavity is a dihedral reflector that acts as a "2D corner cube", so that the resonator remains perfectly in tune irrespective of small misalignments.

Its novel, proprietary optical design provides a unique range of user benefits:

- *Wide, Fast, Truly Continuous Tunability:* Extremely smooth scans over 100 nm (TUNICS 1550) or 70 nm (TUNICS 1300) are obtained in 2 seconds, with 1 picometer resolution. Digitally-controlled analog fine tuning extends resolution beyond the 1 picometer steps into the MHz domain.
- *Mode Hop-Free Operation:* Guaranteed 70 nm (40 nm for TUNICS 1300) range free of any mode hop ensures smooth and accurate wavelength sweep for reliable testing of narrow band components.
- *High Output Power:* More than 0 dBm over 70 nm and -3 dBm is guaranteed over the entire spectral range.
- *Outstanding Long-term Stability:* Self-aligned optical lay-out, single-moving-part design and all-invar construction insure high long term stability.

• *Instinctive, User-Friendly Controls:* Keyboard and display are optimized for natural, unambiguous laboratory operation. All parameters may either be keyed in or adjusted using the multi-speed rotary control.

• *Multiple Modulation Possibilities:* Analog and digital modulation of the optical power from DC to 1 GHz is easy and the cavity is designed to allow mode-locked operation around 5 GHz. The 100 KHz linewidth can also be degraded to 100 MHz when high coherence is a problem.

• *Easy System Integration:* Computer interfaces and analog inputs and outputs allows complete remote operation and makes system integration easy.

Specifications

	TUNICS 1550	TUNICS 1300
Wavelength range (P= 0 dBm)	1500/1570 nm	1280/1320 nm
Wavelength range (P=-3 dBm)	1480/1580 nm	1260/1330 nm
Mode hop free range (P=-3 dBm)	1500/1570 nm	1280/1320 nm
Absolute wavelength accuracy	±0.2 nm	
Tuning accuracy [1]	±0.02 nm	
Tuning repeatability [1]	±0.005 nm	
Wavelength setting resolution	0.001 nm	
Optical frequency fine tuning range	±2GHz	
Power stability	± 0.01 dB p.p. on 1 hour	
Wavelength stability [2]	0.001 nm	
Typical linewidth (FWHM) [1]	100 kHz	
Linewidth with coherence control	>100 MHz	
Side frequency suppression ratio [3]	> 35 dB	
Operating temperature	15-30 °C	
Optical connector	FC/APC	
Remote control	RS-232 and IEEE-488.1	
Power supply	110-230 V	

Notes : 1 : On the mode hop free range

2 : At constant temperature

3 : Measured with a 100 MHz resolution Fabry-Pérot interferometer.

I. GETTING STARTED

I.1 SAFETY CONSIDERATIONS

CAUTION : TUNICS has a chassis connected to earth via the power supply cable. To avoid the possibility of injury, insert the power cable only into a socket outlet provided with a protective earth contact. Before switching on the instrument, check that the electrical installation fulfills the local safety requirements.

CAUTION : TUNICS has not been designed for outdoor use. To avoid the possibility of injury, do not expose the instrument to rain or excessive moisture. Do not operate the instrument in the presence of flammable gases or fumes.

CAUTION : Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

CAUTION : The use of optical instruments with this product will increase eye hazard. Under no circumstances look into the end of an optical cable attached to the optical output when the device is operational. The laser radiation is not visible to the human eye, but it can seriously damage your eyesight.

According to IEC-825 and to CFR-1040, TUNICS is a class 1 laser product. The optical specifications are as follows:

Model	1550	1300
Laser class :	1	1
Output power:	< 10 mW	< 10 mW
Beam diameter :	9 mm	9 mm
Numerical aperture:	0.1	0.1
Wavelength range	1460/1580	1260/1330

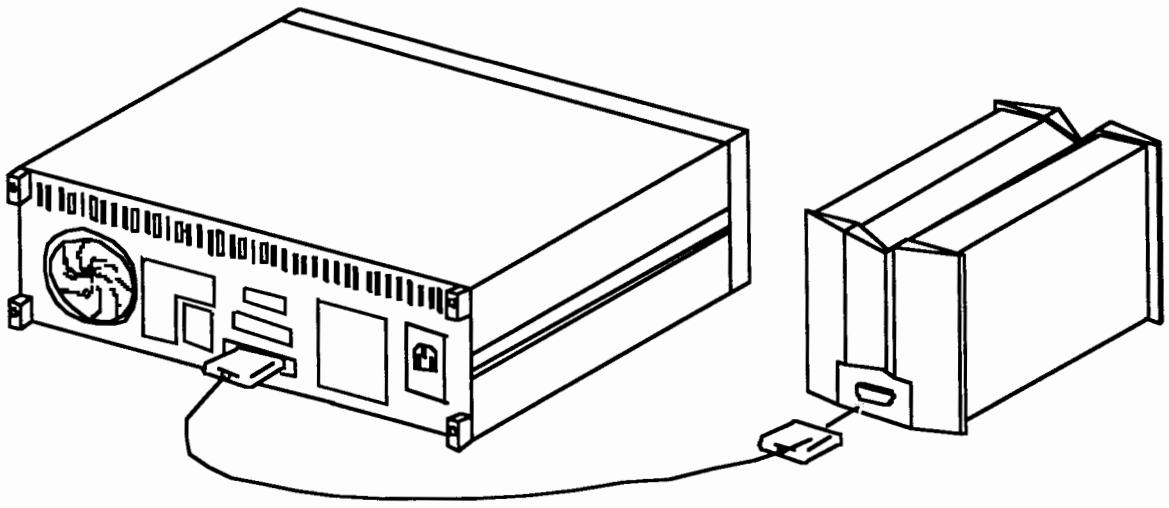
CAUTION : Under no circumstance, the user has to make any service or maintenance of any kind on the laser head. The protective cover of the laser head must not be removed by the user. Refer servicing only to authorized personnel from Photonetics.

I.2 SETTING UP THE INSTRUMENT

For TUNICS PR, plug the provided electrical cable from the laser head into the receptacle provided on the controller. On both devices, the electrical cable termination is a SUBD-50 type connector. For TUNICS PRI, the optical head is integrated inside the controller so that no external connection is needed.

Connect the power supply cable to the rear panel of the controller and then to the proper voltage mains supply point.

Set the main switch at the rear panel controller on the "I" position.



Cable connections between laser head and controller of TUNICS PR

WARNING : To obtain the optimum performances of the system, it is recommended to place the optical head on a stable surface, isolated from any source of vibrations.

WARNING : The cleanliness of the optical connectors are important to get the optimum performance of the system. Ensure that your connectors are clean at all time.

WARNING : The standard output connector is a FC/APC type connector. Never connect another type of connector on the optical output.

I.3 SYSTEM INITIALIZATION

WARNING : If the TUNICS unit has been turned off, it is **imperative** to wait at least thirty seconds before powering it up again.

Turn the front panel on/off key to the right. During the initialization phase, the message **"Initializing..."** is displayed.

At the end of the initialization phase, the cavity is tuned to give an emission wavelength of 1520 nm for TUNICS-1550 and 1320 nm for TUNICS-1300.

All key lights are then extinguished except the APC light, which indicates this mode is active. Current and power settings are initialized to zero when the device is powered up.

WARNING : For safety reasons, TUNICS has an Enable key to enable or disable the laser output. At the end of the initialization, TUNICS is in the disabled mode. To allow light emission press the Enable button.

I.4 SYSTEM SHUT DOWN

WARNING : You should avoid switching the unit off before the system is fully initialized. An initialization message is displayed during the initialization phase, and is cleared once TUNICS is ready for operation.

To shut down the device, turn the front panel key to the left. The message **"Parking..."** is displayed, and the optical head is automatically moved to its parking position. After a few seconds, the system shut down by it-self.

II. USING TUNICS COMMANDS

II.1 DESCRIPTION OF THE FRONT PANEL

The TUNICS front panel is divided into four windows :

POWER : To turn the system on and off

DATA : To display the wavelength, the optical power, diode current and messages.

MODES : Selection of the operating mode.
Selection of the parameter to be modified.

SETUP : User interface to enter the parameter value.

The different function keys are described in the next sections:

II.1.1 DATA area

This area displays the three basic operating parameters (wavelength λ,f, light power output P and the diode laser current I) and is also used by the system to display messages. 3 function keys are included :

nm/GHz : To display either the wavelength in nm or the optical frequency in Ghz.

mW/dBm : To display the power either in dBm or mW.

Enable : To enable the optical output. When the disabled mode is active, the message "**Disabled...**" is displayed.

II.1.2 MODE area

This area includes 8 function keys :

λ , f — To change the actual wavelength, select the function λ ,f and enter the new value. See the section " Entering Numerical Values".

P — To change the actual output power, select the function P and enter the new value. See the section " Changing a parameter".

I — To change the actual diode current, select the function I and enter the new value. See the section " Changing a parameter".

STEP — At any time it is possible to increase or decrease the wavelength by pressing the ← or → on the keypad. The value of wavelength step is given by the STEP parameter. To change this parameter, press the STEP key and enter the new value. See the section " Changing a parameter".

APC — The APC (Automatic Power Control) key is used to switch the system between "constant current" and "constant power" modes. When the unit is running in the "constant current" mode, the APC key light is off and the diode current level is given by the I parameter. In the "constant power" mode, the APC key light is on, and the diode laser current is controlled in order to ensure an optical power output equal to the P parameter.

Note : The selection of the P key switches automatically the system in the "constant power" mode and the selection of the I key switches automatically the system in the "constant current" mode.

Note: It is possible in the "constant power" mode that the required power cannot be obtained even with the maximum allowable current. In such a case, the current is limited to its maximum value and the optical power is lower than the user-set power value. In this case, the message "Lim" appears at

the left end of the displayed current and power.
(Example : I=120 mA Lim and P = 5.4 mW Lim)

FSC — The FSC key (fine scanning mode) allows a quasi-continuous sweep of the wavelength on a ±2GHz range. Once this mode is selected the wavelength can be continuously adjusted with the modify knob of the SETUP window. The wavelength sweep is displayed in the DATA area in nm or in GHz as selected by the user. To exit the fine scanning, mode press again the FSC key.

Remote — The Remote button has no effect as long as the system is not in the remote mode. The Remote operating mode is entered when data is received by TUNICS on one of its interfaces (RS232 or IEEE 488). In the remote mode,the Remote key light is on.
The Remote key should be pressed to re-enable the front panel keys.

2nd — The 2nd function key allows access to advanced functions. (See the section " Advanced functions"):

2nd λ	Wavelength calibration.
2nd P	Power calibration.
2nd STEP	Wavelength scan mode.
2nd 1	Backlash suppression of the micrometer screw.
2nd 2	Display the software release.
2nd Remote	Change of the GPIB address.

II.1.3 SETUP area

The keypad and the modify knob are used to set or to change the values of the system operating parameters. To change a parameter, the appropriate key inside the **MODE** area should first be pressed, illuminating its indicator light. The display will show the present setting for the chosen parameter, which is then accessible for modification by the number keypad, and the modify knob. The "=" sign of the display is blinking showing that this parameter can be modified. To quit this edition mode press again the key corresponding the edited parameter.

WARNING : When the modification is made with the keypad, the new value is taken into account after the modification is enabled by pressing the "Ent" key. At the opposite, when the modification is done through the modify knob, the value is updated in real time.

The parameters that can be changed are:

The emission wavelength	:	λ , f
The optical power	:	P
The diode current	:	I

Edition of parameters is also done in the following modes :

Wavelength step	:	STEP
Wavelength scan	:	2nd STEP
Power calibration	:	2nd P
Wavelength calibration	:	2nd λ,f

II.2 ENTERING NUMERICAL VALUES

The modification of a parameter can be done either from the keypad or the modify knob :

II.2.1 Using the number keypad

To edit a parameter, first select the parameter by pressing the associated key (λ,f or P or I) and enter the new value on the keypad. The new value is taken into account after validation with the "Ent" key. To exit the edition mode without saving the new value, press again the parameter key (λ,f or P or I). The arrows can be used to correct typing errors.

For instance to enter a power of 0.5 mW type the following sequence:

P	Parameter selection
0.5	New value (.5 is also valid)
Ent	Validation of the new value.

Note : If the new value keyed in is outside the valid range for the selected parameter, the operator is informed by an error message (Value error, press Ent). The operator must then press the Ent key to continue; the former setting is kept unchanged and any process (scanning or calibration) currently running will be suspended. (Please see details of valid ranges for each system parameter later in the annexe B.)

II.2.2 Using the modify knob

To modify a parameter with the modify knob, press the desired parameter key (λ,f or P or I). The actual value is changed in real time when rotating the modify knob.

The elementary step given by the modify knob can be increased or decreased with the two ↓ and ↑ arrows below the knob. The message like "Scroll 0.01" appears in the display area when one of the two ↓ and ↑ arrows are pressed, to indicate which digit is actually changed by the modify knob.

WARNING : TUNICS software integrates a procedure to eliminate the effect of the backlash of the tuning micrometer screw, but since the wavelength change is done in real time with the modify knob, this procedure is not used in this mode. This is indicated by a dot "." at the right end of the wavelength display.

Example : λ=1555.000 nm .

The backlash suppression procedure will become active again at the next wavelength edition, for instance by pressing the λ,f key (to enter the edition mode) then the Enter key (to validate the actual value).

II.3 ADVANCED FUNCTIONS

II.3.1 Wavelength scanning

The wavelength scan mode is activated by pressing the 2nd STEP key. The various parameters necessary for operation in the scan mode are displayed one after the other for confirmation or modification by the operator. These parameters are the following :

The initial scan wavelength	(message : Enter first λ)
The last scan wavelength	(message : Enter second λ)

The scan increment (message : Enter scan step)

The pause time between two scan steps (message : Enter pause dt)

For each parameter the system proposes a default value corresponding to the previous wavelength scan. For each parameter the Enter key has to be pressed after modification to edit the next parameter.

Pressing again the STEP key will cause the entire scan procedure to be canceled. However, the parameter settings which have been already entered will still be retained.

When all the parameters have been set, scanning begins. The system first begins by going to the first scan wavelength. The wavelength is then incremented step by step (applying the scan step parameter value) until the upper scan wavelength limit has been reached. At each step the wavelength remains constant during the pause time parameter.

When the upper wavelength scan limit has been reached, the system go back to the initial wavelength and the process will repeat indefinitely (except in remote mode : in this mode, scan is ended when the upper wavelength is reached).

When the operator presses the STEP key during wavelength scanning, scanning is suspended and a message asks the operator to confirm that scanning is to be terminated: Stop scan (1/0) ? If the operator then hits 0, scanning is resumed from the point at which it was suspended. If, however, he or she presses 1, scanning stops and the emission wavelength remains at the value in effect at the time when scanning was aborted.

Note : The operator cannot change any parameter in the wavelength scan mode. For this reason you should select the operating mode (constant power or constant current) and the relevant value for power or current before starting a scan. If APC mode has been selected, the power level value must be chosen to ensure that even at the both wavelength scan limits, power can be achieved without exceeding the current limit. If this is not the case, scanning will still be performed but the output power will not remain constant throughout the scan. This situation will be indicated by the display of the Lim symbol.

II.3.2 Wavelength calibration

WARNING : TUNICS offers a simple procedure to calibrate the system against another instrument. Since this procedure erases the factory calibration data, it must be used with a great care.

Wavelength calibration can be initiated by pressing first the 2nd key (which may be thought of as a "shift" function), followed by the λ key.

During calibration, the source moves first to a position corresponding to a short wavelength of the tuning range. A message then prompts the operator to enter the actual wavelength of the emitted light (Enter first calibration λ). The default value corresponding to the actual calibration data is also displayed.

When this value has been entered, the source is moved to a long wavelength of the tuning range, and a second message is displayed (Enter second calibration λ). The operator must then key in the second calibration wavelength. The default value corresponding to the actual calibration data is also displayed.

After entering the two new calibration wavelength, the procedure is over and all wavelength modification instructions will be referenced to the new calibration.

II.3.3 Power calibration

WARNING : TUNICS offers a simple procedure to calibrate the system against another instrument. Since this procedure erases the factory calibration data, it must be used with a great care.

Power calibration is initiated by pressing first the 2nd key followed by the P key. During calibration, the laser source emits successively at two distinct wavelengths within the overall waveband. The operator must key in the two actual power levels as read by an external power-meter.

The procedure is as follows : The output power is set automaticallyto 0.5 mW, and the wavelength to 1500nm (or 1290 nm for 1300 systems). A message then prompts the operator to enter the corrected power level read by an external powermeter (P=). When this value has been entered, the system is set to 1560 nm (1320 nm for TUNICS 1300). A message then prompts the operator to enter the actual power level read by an external power-meter (P=).

When this has been done, the procedure is over and all instructions will be referenced to the new calibration.

II.3.4 Backlash suppression of the micrometer screw

TUNICS software integrates a procedure to eliminate the effect of the backlash of the tuning micrometer screw. This procedure may be canceled with the function 2nd 1. This is indicated by a dot "." at the right end of the wavelength display.

Example : λ=1555.000 nm .

The backlash suppression procedure will become active again by pressing again the function 2nd 1.

II.3.5 Changing the GPIB address

The default GPIB address of the system is set to 10 at the delivery. It is possible to change this address by pressing 2nd Remote.The system display the actual address and prompt for the new value.

II.4 REMOTE CONTROL

When TUNICS receives data from the RS232 or the IEEE 488 interfaces, it enters the remote control mode and the indicator light on the Remote key is switched to ON. When the TUNICS unit is operating in this mode all keys are disabled except the Remote key. To exit the Remote mode, press the Remote key.

NOTE : If the unit receives a message through the serial interface ending with a "CR" character, the remote mode is automatically activated (even if the message itself is invalid).

III. THE RS-232C REMOTE CONTROL MODE

In the remote mode (the unit is in this mode when the Remote key light is on) all the keyboard keys are disabled and all the commands can be sent to the system through the RS-232C interface. Additional specific commands are also available using this interface.

III.1 REMOTE CONTROL PROTOCOL

III.1.1 Physical interface

The cable link is a three-wire RS-232C type using a SUBD9–pin plug. The TUNICS serial port is configured in "Terminal" mode: Data sent to TUNICS must be present on pin 2 of the connector and return messages from TUNICS are on pin 3. The ground is through pin 5. No other connector pin is used.

The serial port is configured as follows:

Data transmission rate..... 9600 bauds
Number of bits..... 8
Parity ..... no
Stop bits..... 1

III.1.2 Message format

All commands sent by the computer to TUNICS are composed of a string of ASCII alphanumeric characters followed by a "carriage return" character (CR, or ASCII code 13). When such an instruction is received by TUNICS the character string is decoded and the relevant procedure is carried out.

After completion, TUNICS returns a message to inform the computer that the requested procedure has been performed or that an error situation has been encountered. This response message is always terminated by the same end-of-message group: **"↵" (= carriage return), ">" (= "greater than") and " " (= space character)**. These three characters indicate that the TUNICS

system is ready to receive a new instruction.

Example:

Computer to TUNICS -

APCON↵	(Transmission of instruction APCON by computer)

TUNICS to computer -

OK↵	(Instruction correctly performed)
>	(TUNICS is awaiting another instruction)

Computer to TUNICS -

I = 160↵	(Change current value to 160 mA)

TUNICS to computer -

Value error↵	(current level over permitted maximum)
>	(TUNICS is awaiting another instruction)

Computer to TUNICS -

L?↵	(What is the present wavelength value?)

TUNICS to computer -

L = 1523.325↵	(Present wavelength value)
>	(TUNICS is awaiting another instruction)

The message syntax described above eases the management of the TUNICS/computer interface since the computer must await the acknoledgement before sending a new instruction. In addition, the response from TUNICS is always terminated by the three characters "↵", ">" and "space", enabling easy end-of-message detection.

Note : TUNICS does not distinguish between lower and upper case alphabetical characters in the messages it receives.

Note : It is possible to send a series of instructions in a single string: successive instructions should be separated by ";", and string should be ended with a carriage return character "↵". The different instructions will be analyzed as soon as the "↵" character is received, and will be executed in sequence. TUNICS input buffer length is 255 characters ; if more than 255 characters are sent in a single string, or before previous strings have been analyzed, the buffer will be cleared, all received instructions lost, and the message "command error" sent.

Note: "White space"[1] characters are allowed in some places inside the strings sent to TUNICS : they can be placed at the beginning of an instruction, after an instruction, before, after or in place of the "=" character. They cannot be inserted within an instruction mnemonic, within a numeric value, or between a mnemonic and the "?" character.

III.1.3 TUNICS System Response Messages

All instructions requesting a parameter reset or a change of operating mode give rise to an "OK" acknowledgment (terminated by "↵", ">" and "space" as for all responses) from TUNICS when the command has been correctly executed. The only exception to this general rule is the "SCAN" command, since the acknowledgment in this case is "Scanning..." which is sent as soon as scanning has begun, followed by "End of scan" when scanning has been terminated.

If a command is not recognized by TUNICS, the message returned will be "Command error". If a command requesting a new parameter setting is correctly formulated but the specified value is outside the allowed limits for that parameter, the setting will remain unchanged and the response is "Value error".

III.1.4 Value format

Some command messages include a value. The format rules for these values are as follows :

- No spaces (see note 1) are allowed within values ; leading zero ("0") characters are allowed at the beginning of a value.
- Figures after the decimal point may be sent or omitted.
- Figures after the decimal point are sent after the characters "." or ","
- Values are terminated by the "CR" character. No unit abbreviations must be sent.

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[1] On the RS232 interface, all characters with ASCII codes lower than or equal to 32, except the carriage return character (ASCII code 13) are considered as white space characters.

Examples :

I=5	Correct: 5.0 mA
P=0.22	Correct: 0.22 mW
L=1530.2	Correct: 1530.200 nm
P=01	Correct : 1 mW
I= 25	Correct (spaces before figure)
I=25 mA	Incorrect (no unit abbreviations)
Smin=1 520.31	Incorrect (space between "1" and "5")

III.2 LIST OF SYSTEM COMMANDS

III.2.1 Changing parameter settings

Wherever "nn.n" occurs below, it stands for the transmitted numerical value. All commands must be terminated by the "CR" character.

Responses sent by TUNICS may be :

OK..... Command executed
Value error..... Value outside valid limits
Command error..... Syntax error

The command list for parameter settings is given hereafter:

I=nn.n	Sets the laser current level (in milliamps) and switch to the constant current mode.
P=nn.nn (1)	Sets the the optical power (in milliwatts) and switch to the constant power mode.
P=±n.nn (1)	Sets the the optical power (in dBm) and switch to the constant power mode.
L=nnnn.nnn	Sets the wavelength (in nanometers). The "OK" acknowledgment is sent when the emission wavelength is stabilized.
f=nnnnnn.n	Sets the optical frequency (in GHz). The "OK" acknowledgment is sent when the emission wavelength has stabilized.

Note (1) : See commands DBM or MW

FSCL=nn.n	Switches to the Fine Scanning mode. nn.n is the wavelength change in picometers.
FSCF=n.nn	Switches to the Fine Scanning mode. n.nn is the optical frequency change in GigaHertz.
Smin=nnnn.nnn	Lower limit scanning wavelength.
Smax=nnnn.nnn	Upper limit scanning wavelength.
Step=n.nnn	Wavelength scan step.
Stime=nn.n	Stop time in seconds between each scan step.

III.2.2 Changing the operating mode

APCON	Switch system operation to the "constant power" mode.
APCOFF	Switch system operation to the "constant current" mode.
SCAN	Initiation of wavelength scanning. TUNICS response message is "Scanning..." when scanning starts, followed by "End of scan" when scanning is terminated. **Note :** Unlike scanning initiated locally using the TUNICS controller keypad, once the upper wavelength scan limit has been reached, scanning terminates; it does not start again at the lower wavelength scan limit. **Note** : Each parameter can be altered individually without changing the others and the previous parameters are retained from one scan session to the next.
STOP	This command stops the scan procedure. When scanning is terminated, the message "End of scan" is sent by TUNICS. **Note :** While scan is running, all commands are disabled (this is indicated by the response message "Command error"), with the exception of parameter value requests and the STOP instruction.
DBM	Selects dBm units for transmission of optical power values to and from TUNICS, and for displayed values.
MW	Selects mW units for transmission of optical power values to and from TUNICS, and for displayed values.
INIT	Initialization of the optical head.
ENABLE	To enable the optical output.
DISABLE	To disable the optical output.

III.2.3 Reading system parameters

The system parameters for power output, current level and wavelength can be read by the operator at any time :

I ?	Request the present current level. System response : "I=nn.n" (in mA) or "disabled" if the Enable mode is not active.
P ?	Request the present power output level. System response : "P=nn.nn" (in mW) or "P=±nn.nn" (in dBm) or "disabled" if the Enable mode is not active.
L ?	Request the present wavelength value. System response : "L=nnnn.nnn" (in nm).
f ?	Request the present optical frequency value. System response : "f=nnnnnn.n" (in GHz).
LIMIT?	The answer is "Yes" if the current is limited and "No" otherwise.

III.2.4 Other system commands

ECHON	When this mode is active, TUNICS sends an echo of each character received back through the serial cable. Since some terminals and terminal emulation programs do not feature local echo, this function can be useful for visual monitoring of the characters keyed in at the terminal.
ECHOFF	Cancels "echo" mode. **Note** : The default option is that ECHOFF. Additionally, when remote mode is canceled using the TUNICS keyboard and is then re-activated, the echo mode is switched to ECHOFF.

IV. THE IEEE-488.1 REMOTE CONTROL MODE

IV.1 INTRODUCTION

The "GPIB" communication link of TUNICS is compatible with the standard IEEE-488.1. The controlling computer can send to TUNICS the instructions defining its method of operation, and it can ask TUNICS to send the values of certain parameters. In addition, the status word of TUNICS is accessible to the controller at all times ; this permits to process some operations using this status word.

The elementary procedure of communication is quite simple : the instructions are sent by the controller on the GPIB link with one string of ASCII characters for each instruction. These instructions can be either definition instructions for the operation of TUNICS (for example, "Set the level of the current to 35 mA" by sending "I=35") or requests of a parameter value (for example, " I ? " to ask for the value of the current level). Each instruction/request is immediately handled by TUNICS microprocessor.

The reading of the value is done by addressing TUNICS as the "talker" and the value is transmitted by TUNICS on the GPIB link for reading by the computer. For example, if the value of the current has been requested by the computer (instruction "I?") and the TUNICS is addressed as "talker," the transmitted response on the link will be in the form "I=35".

WARNING : To accelerate and secure the exchange of informations between the controller and TUNICS, we recommend to use the value of the status word obtained by the serial polling (see § IV.4.3). This status word contains the information allowing the controller to know the status of commands received by TUNICS, and therefore to decide when a new instruction can be sent or when the requested parameter can be read . This applies particularly when reading a parameter value: the bit MAV (message available) indicates that the requested parameter value has been measured and that answer message is available.

IV.2 DEFINITION OF COMMANDS

IV.2.1 Protocol of messages

The following protocol applies for the transmission and reception of messages:

• Each message sent by the controller to TUNICS must end either with the "line-feed" character (LF, ASCII code10), or with the "EOI" GPIB message (or with both together).

• Each message may contain one instruction or more. If more than one instruction is sent, successive instructions should be separated with the ";" character.

• Numeric values must be transmitted in a fixed-decimal-point format for non-integer values (values of the current, for example) and without a decimal point for integer values (the validation byte of the request condition for service of the SRE instruction, for example).

• White space characters[1] can be placed within a message at certain positions ; they can be placed before an instruction, at the end of an instruction, instead of, after, or before the "=" sign. It cannot be placed within a mnemonic, nor within a numeric value, nor between a mnemonic and the "?" character.

• All alphabetic characters can be either upper or lower case letters.

• The instructions for parameter modification are composed of the name of the parameter, the "=" sign, and the value of the parameter. The parameter-request instructions are composed of the name of the parameter and the character "?". A value's unit must never be indicated. (The unit applicable to each parameter is indicated below.)

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[1] On the IEEE488 interface, white space characters are all characters whose ASCII code is smaller than or equal to 32, except the line feed character (ASCII code 10).

IV.2.2 Messages

Definition of operating parameters

In the following, each "n" represents a numeric character between 0 and 9.

Message	*Meaning*
I=nn.n	sets laser-diode current to *nn.n* milliamperes.
P=nn.nn (1)	sets emitted power to *nn.nn* milliwatts, and switch to the constant power mode.
P=±nn.nn (1)	sets emitted power to ±nn.nn dBm.
L=nnnn.nnn	sets emission wavelength to *nnnn.nnn* nanometers.
f=nnnnnn.n	sets emission optical frequency to *nnnnnn.n* GHz.
FSCL=nn.n	Switches to the Fine Scanning mode. nn.n is the wavelength change in picometer.
FSCF=n.nn	Switches to the Fine Scanning mode. n.nn is the optical frequency change in GigaHertz.
Smin=nnnn.nnn	sets *initial* wavelength for a scan (in nm).
Smax=nnnn.nnn	sets *final* wavelength for a scan (in nm).
Step=nn.nnn	sets wavelength step for a scan (in nm).
Stime=nn.n	sets the pause duration (in seconds) during a scan.
***SRE=nnn**	defines the conditions under which TUNICS will automatically send a service request (SRQ) to the controller.
GPAD=nn	defines the TUNICS GPIB address.
LCAL1 =nnnn.nnn	defines the first calibration wavelength.
LCAL2 =nnnn.nnn	defines the second calibration wavelength.
PCAL1 =nn.nn	defines the calibration power (first wavelength).
PCAL2 =nn.nn	defines the calibration power (second wavelength).

Note (1) : The units (dB or mW) should be first selected with the DBM or MW command.

Request for parameters value

I ?	asks for the value of the laser diode current (mA).
P ?	asks for the value of the optical power (mW or dBm). The unit is selected by the commands **DBM** or **MW**.(see below "definition of operating modes"
L ?	asks for the value of the emission wavelength (nm).
f ?	asks for the value of the optical frequency (GHz).
***IDN?**	TUNICS returns the message "PHOTONETICS, TUNICS2,xxxxxx,n.nn" where n.nn is the software release.

Definition of operating modes

APCON	turns the Automatic Power Control on.
APCOFF	turns the Automatic Power Control off.
SCAN	starts a wavelength scan. The scan will use the Smin, Smax, Step and Stime values.
STOP	interrupts an ongoing wavelength scan.
DBM	switch TUNICS in the dBm mode.
MW	switch TUNICS in the mW mode.
ENABLE	enables the laser output.
DISABLE	disables the laser output.

Conditions of use

Some instructions can only be used under specific conditions:

- During a wavelength scan (SCAN instruction), only the request instructions for parameter's value and the instruction STOP are valid. All other commands will be ignored and will activate the ERRC (command error) indication.

- The STOP instruction is only valid during a wavelength scan. If this instruction is transmitted without a scan in process, the ERRC (command error) indication will be activated.

GPIB standard

The messages corresponding to the IEEE-488.1 standard are normally processed by TUNICS, and are not specifically described here (see the IEEE-488.1 standard description). All messages concerning the parallel polling are not executed by TUNICS. Also, TUNICS does not offer the extended addressing capability.

Synchronization of messages

Several instructions can be contained in a single message, and several messages can be transmitted, even if previous messages have not been executed. However, this should only be done if successive instructions in a message do not interact (as for example setting of all the scan parameters). If a given state is to be reached before some instruction is to be executed, it is preferable to make sure this state has been reached, by reading the system status word through the serial poll instruction.

When instructions are received, each one is executed as soon as it is complete (";" character or "If" or EOI received) provided that TUNICS is not busy at another task. This implies that some instructions of a message can be executed even though the message is not completely transmitted. Successive instructions of a message are executed in sequence. The execution of an instruction is composed of : decoding the character string for the instruction, possible modification TUNICS operating state, and/or elaboration of a response string, and/or modification of some bits of the status word.

If the previous message included a request for a parameter's value, serial polling shall be repeated until the MAV indicator in the status word answered by TUNICS is activated (MAV = 1). Only then can the computer read the requested parameter's value. If several requests have been made in a single message, bit MAV will stay true until all answer messages have been read by computer.

IV.3 TREATMENT OF ERRORS

Two types of errors can arise in the transmission of instructions : command errors and value errors.

The system detects command errors when the received string of characters does not correspond to an authorized instruction (syntax error or unknown mnemonic). The ERRC indicator in the status word is then activated.
A value error arises when the command is valid, but the value of the parameter is incorrect, either because it could not be read or because it is outside the valid range. In both cases, the received message is ignored and the ERRV indicator in the status word is activated.

IV.4 STATUS WORD

IV.4.1 Definition of the status word

The 8-bit TUNICS status word contains a number of binary indicators which can be used by the controller for an optimal synchronization between TUNICS and the controller. They indicate to the controller the nature of the current operations as well as the errors encountered. These binary indicators are contained in the word sent by TUNICS when the computer performs a serial polling.

Bit #	*Mnemonic*	*Meaning*
7 (MSB)	SCANNING	wavelength scan in progress
6	SRQ	service request: request for controller intervention
5	ESB	(reserved for future use)
4	MAV	message available: a message is available for reading
3	LIM	current limitation
2	ERRV	error in received parameter value
1	ERRC	error in received command
0	OPC	operation complete: the operation has been completed; TUNICS is ready to receive a new instruction.

IV.4.2 Activation and deactivation of status word indicators

In the active state, a value 1 is read for each indicator. When these indicators are inactive, the value 0 is read.

SCANNING activated at the beginning of a wavelength scan.
deactivated at the end of the scan.

SRQ activated when an occurrence defined by the instruction *SRE arises.
deactivated when it has been read by a serial poll.

ESB (reserved for future use; value is always 0)

MAV activated when the response to a parameter request is ready to be sent.
deactivated when the response has been read, and no other answer message is available.

LIM activated when TUNICS is current-limited in the APC mode (see APC).
deactivated in all other cases.

ERRV activated upon receipt of a parameter value which either has not been read, is erroneously formatted (e.g., the units have been indicated), or is outside the acceptable range (e.g., I=160).
deactivated upon the reception of a correct instruction.

ERRC activated when an erroneous command has been received.
deactivated when a valid command is received.

OPC activated when no operation is in progress in TUNICS
deactivated during the handling of commands (and also, during shifting of the drive to modify the wavelength emission). In particular, during scan operation, OPC bit is set to 0 each time the motor is moving and set back to 1 during the pause between successive steps.

Note : When messages containing only one instruction are sent, testing of the bits ERRV and ERRC of the status word after each message enables the user to detect all errors that might occur. When a message contains several instructions, ERRV and ERRC flags are

relevant to the last instruction only. It is suggested that the SRE bits corresponding to ERRC and ERRV be activated, so that service is requested by TUNICS as soon as an error is encountered; if this method is used, no error will occur without being detected.

IV.4.3 Use of the status word

The status word can be read by the computer at any time by performing a serial poll. The computer shall check the state of the different binary indicators to perform the next operation accordingly. Examples of use are given below :

- After having sent an instruction defining a new value for wavelength, current or power, the computer should control the condition of the OPC indicator before sending a new instruction, in order to be certain that the new parameter's value is stabilized.

- After each instruction, it is recommended to check that the indicators ERRV and ERRC are deactivated (= 0), which shows that there has been no transmission error.

- When a parameter's value has been requested by the computer, it is recommended to check the state of the MAV (message available) indicator before reading the value. (If the reading is made before the message is available, the response of TUNICS will be a string of empty characters ending with the "LF" character.)

The different indicators for the status word are updated by TUNICS according to the state of the internal functions of the system. When the computer reads the status word, the value read corresponds to the actual state of the system. No memorization is performed, and the different indicators are automatically activated or deactivated according to the criteria described above, even if no messages are transmitted on the GPIB link.

However, if a service request has been activated by TUNICS, the status word will no longer be updated until the serial poll has been performed. (See below.)

IV.4.4 Use of the service request (SRQ)

The SRQ (service request) line is a part of the definition of the IEEE-488.1 standard. This line can be activated by all devices on the bus to alert the central controller that a particular device requires a particular operation.

When the controller detects that the SRQ line is active, it can question all of the devices present on the bus to determine which one has initiated the service request and for what reason. For this, it performs a serial poll, during which it will read the status word of each device (see paragraph 4.1) which regroups the indicators permitting the controller to monitor the progress of the polling.

The IEEE-488 standard imposes the condition that Bit # 6 of the status word be set to 1 if the interrogated device has sent a service request. The other bits can reflect the state of different logical indicators of the system.

To facilitate the synchronization between the operations initiated by the computer and by TUNICS, the computer can request TUNICS to activate a service request when certain indicators move to 1 by using the instruction *SRE. In this fashion, the computer will be warned that a particular occurrence has happened, without having to repetitively read the status word of TUNICS to detect this occurrence.

The command *SRE permits the definition of the conditions in which TUNICS will perform a service request. The transmitted parameter with the instruction *SRE must be an integer value between 0 and 255. If one writes this value in the form of a binary byte of 8 bits, the binary elements (bits) which are at 1 validate the service request upon activation of the corresponding indicators of the status word.

Example : If the instruction *SRE=16 is received by TUNICS, this corresponds to the binary value 00010000; Since in this example the indicator #4 is set to one (indicator #4 = MAV = message available), the SRQ line will be automatically activated each time a message is available.

Different incators can be set to one :

SCANNING	128	: indicator #7
MAV	16	: indicator #4
LIM	8	: indicator #3
ERRV	4	: indicator #2
ERRC	2	: indicator #1
OPC	1	: indicator #0

To calculate the parameter value to send with the instruction *SRE, you must add the corresponding value of each of the indicators (bits) for which one wishes a service request in case of activation. Example: to obtain a service request each time an error is made, you must send the instruction "*SRE=6", (obtained by adding the corresponding values of the two error indicators, which are ERRV(4) and ERRC(2)).

Once a service request has been activated by TUNICS, the status word is no longer modified, as long as the controller does not perform a serial poll on the GPIB link to read the status word of TUNICS. This will allow the TUNICS' indicators to remain in the state which they have had from the moment of the service request, so that the computer can analyze the cause of the service request.

IMPORTANT : This in particular implies that no new instruction can be treated until the computer has performed the serial poll, since the processing of an instruction begins with the deactivation of the OPC indicator. It is therefore necessary that, when a service request is received by the computer, a serial poll be performed as soon as possible.

Once the status word is read, the service request is deactivated, and the normal activity of TUNICS resumes.

IV.5 CHANGE OF THE GPIB ADDRESS

At the time of the TUNICS system's factory configuration, its address on the GPIB link is 10. The operator can change this address at any time by pressing the "2nd" key, then the "Remote" key. The current address is then displayed on the TUNICS screen, and a new value can be entered.
This modification can also be performed with the IEEE command : "GPAD=nn".

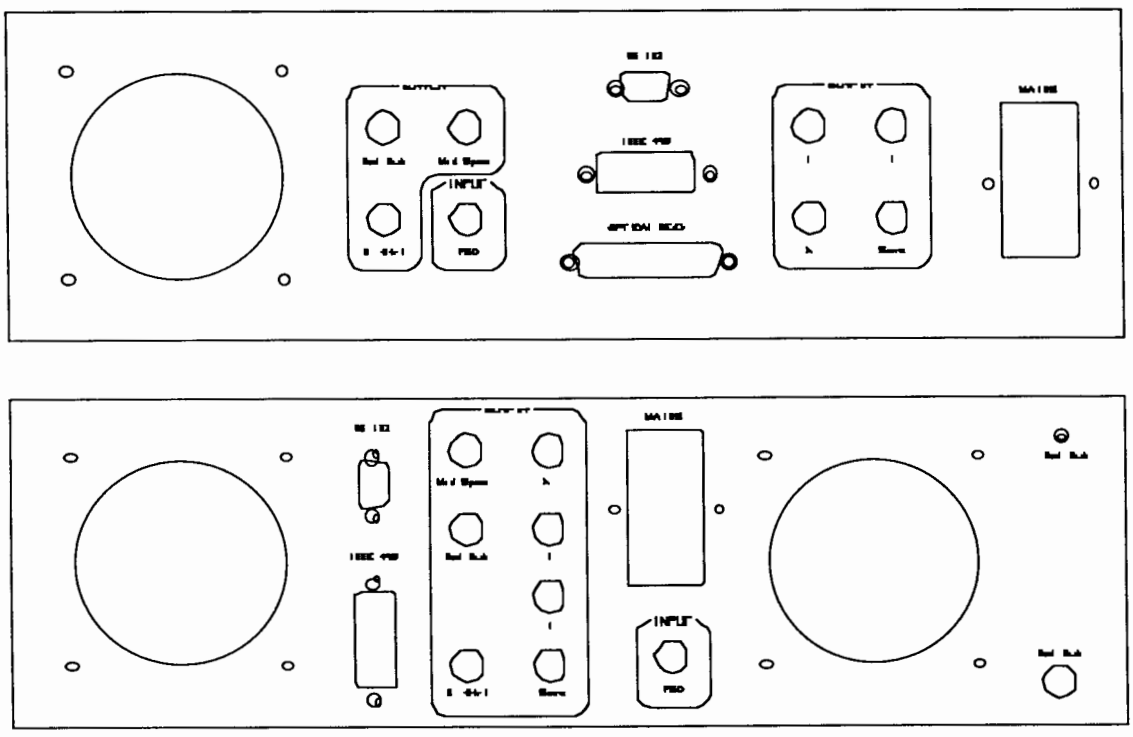
When the GPIB address has been modified, the new value is stored in protected memory, and it is therefore retained even if TUNICS is turned off. This new value then replaces the initial value of the address, which is lost.

IV.6 LOCAL LOCKOUT

When TUNICS receives a message through its IEEE-488.1 interface, it switches automatically to the remote mode of operation and the "Remote" indicator on the front panel lights up. In this operating mode, all keys of the TUNICS front panel are deactivated. The local operating mode can be re-activated by pressing the "Remote" key.

If the message "Local lockout" is sent to TUNICS through the GPIB link, the remote mode cannot be deactivated through the keys, and only the computer can resume TUNICS to the local mode by sending the message "Go to local". In this case, the message "Local lockout" is displayed on the TUNICS front panel when the Remote key is pressed.

V. AUXILIARY INPUTS AND OUTPUTS



V.1 BEAM MODULATION

Low frequency modulation

It is possible to implement low frequency intensity modulation of the output beam from DC to 8MHz. This is obtained by applying a 0 to 5 Volts signal on the BNC connector of the laser head for TUNICS PR or on the BNC noted "Mod BF" located on the rear panel of the TUNICS PRI. For On/Off modulation, a TTL signal can be used from DC to 1MHz.

Principle of low frequency modulation operation:

When the laser is used in the constant current mode, with an operating current I, the actual current in the diode is given by $I_{diode} = I - \frac{V}{R}$, where V is the applied voltage on the low frequency connector, and R is a 50 Ω internal resistor. If the resulting value is lower than zero, the actual current in the diode is zero. If V is lower than 0 Volt, the current in the diode is unchanged.

A 7.8kHz TTL modulation signal is provided at the rear panel of the electronics controller. The corresponding BNC connector is noted "Mod Out". A synchro signal is also provided on the BNC connector noted "Mod Sync".

Note : In the APC mode, the output power is controlled in order to remain constant, which is in principle not compatible with a modulation of the output power. However, if the frequency of the modulation signal is well above the intrinsic frequency (≈ 1 kHz) of the APC loop, the average power is monitored, and remains constant. Modulation is possible in APC mode at frequencies above 10kHz ; if a lower frequency is used, interaction between modulation signal and APC circuit will cause modifications of the output power waveform with respect to the input waveform.

High frequency modulation

The TUNICS PR optical head has a SMA connector input for high frequency modulation, the same feature is available on the TUNICS PRI through the SMA connector located on the rear panel of the controller and noted "Mod HF". The bandwidth is greater than 1 GHz, and this modulation input can be used for analog high frequency modulation and for mode lock operation. The low frequency cut off is 30 kHz.

WARNING : This SMA input is directly connected to the laser diode chip via a 50Ω resistor. It is essential that the user insures that at any time the diode is forward biased to avoid the destruction of the diode.

Low frequency wavelength modulation

TUNICS has a low frequency modulation wavelength modulation capability from DC to about 10kHz. This input is available on the FSC input of the electronics controller.
The maximum input voltage is limited to ±10V and the sensitivity is typically 200MHz/V.

Note : This input can be used for a fine adjustment of the wavelength or for optical frequency locking.

Coherence control

The "Cctl" electronics controller output provides a "noise" signal that can be directly connected to the "FSC" input to modulate the optical frequency on a more than ±100MHz range. The apparent broadening of the line width of the laser is useful to wash out parasitic interferometers in the user setup. This modulation is limited to low frequency (DC to 10kHz typ.).

V.2 MONITOR OUTPUTS

Four outputs connectors located on the rear panel enable continuous monitoring of actual values of current (**I** output), power (**P** output), wavelength (λ output) or motor movement (**Sync**. output). These monitor outputs use BNC connectors. Signal levels are the following :

* Current monitor	40 mV/mA (typ)
* Power monitor	1.2mV/µW (typ)
* Wavelength monitor	25 mV/nm (typ) 0 V corresponds to 1400 nm (TUNICS 1550) or to 1200 nm (TUNICS 1300)
* Sync.	0 V : motor moving 5 V : motor not moving

IMPORTANT : The BNC connectors for the monitor outputs are isolated from both ground and controller base frame. This isolation enables noise levels to be kept to a minimum. It is recommended therefore that when they are in use they should be connected to devices equipped with differential type inputs isolated from ground. It is, however, possible to connect these outputs to devices without this isolation but the ground loop which results will increase noise levels on both the diode control and monitor output circuits. The TUNICS optical output may in this case show higher than normal power fluctuations.

ANNEXE A : ERROR AND WARNING MESSAGES

	Signification	Action
WARNING : User calib. err press "enter"	user calibration not correct	The default value is used instead of the user calibration
ERROR : no factory calib. turn power off	No factory calibration	Switch off the system, test the electrical connections. If the same message is displayed, cal service engineer.
DEFAULT Laser head disconnected	No connection between the head and the controller	Switch off the system, test the electrical connections. If the same message is displayed, call service engineer.
Value error Press Enter	The entered value is not in the valid range	Press Enter. The modification is canceled The previous value is kept unchanged
Limit Switch Turn Power off	Mechanical problem	Switch the system off and call service engineer.
EEPROM error Turn Power off	Electrical problem	Switch the system off and call service engineer.

ANNEXE B : VALID RANGE FOR PARAMETER SETTINGS

Laser diode current level (𝕀)	see attached test report
Beam output power (ℙ)	0.2 to 10 mW
Wavelength (λ)	1457 to 1599,999 nm 1240 to 1360 nm
Upper and lower wavelength scan limits	1457 to 1599,999 nm 1240 to 1360 nm
Wavelength scan steps	0.001 to 20 nm
Time at each scan step	0.1 to 25 seconds

ANNEXE C : SUMMARY OF RS 2323 CONTROL COMMANDS

Command	*Action*	*TUNICS response*
I=nn.n	Sets diode laser current level (mA)	**OK**
P=nn.nn	Sets power output level (mW mode active)	**OK**
P=(±)nn.nn	Sets power output level (dBm mode active)	**OK**
L=nnnn.nnn	Sets emission wavelength (nm)	**OK**
f=nnnnnn.n	Sets emission optical frequency (GHz)	**OK**
FSCL=nn.n	Fine Scanning mode in picometer	**OK**
FSCF=n.nn	Fine Scanning mode in GHz	**OK**
FSCL=nn.n	Fine Scanning mode in picometer	**OK**
FSCF=n.nn	Fine Scanning mode in GHz	**OK**
Smin=nnnn.nn	Sets lower scan wavelength limit (nm)	**OK**
Smax=nnnn.nn	Sets upper scan wavelength limit (nm)	**OK**
Step=nn.nnn	Sets scan step value (nm)	**OK**
Stime=n.n	Sets scan step time (s)	**OK**
APCON	Switches system to constant power mode	**OK**
APCOFF	Switches system to constant current mode	**OK**
MW	Sets power unit to mW	**OK**
DBM	Sets power unit to dBm	**OK**
SCAN	Initiates scan	**Scanning...**
	At termination of scan	**End of scan**
STOP	Terminates scan in progress	**End of scan**
ECHON	All characters sent to be echoed on remote screen	**OK**
ECHOFF	Cancels echo mode	**OK**
INIT	Initialization of the optical head	**OK**
ENABLE	Enable the laser output	**OK**
DISABLE	Disable the laser output	**OK**
I ?	Requests present current level (mA)	**I=nn.n**
P ?	Requests present power output level	
	mW unit active :	**P=nn.nn**
	dBm unit active :	**P=±nn.nn**
L ?	Requests present emission wavelength (nm)	**L=nnnn.nnn**
f ?	Requests present emission frequency (GHz)	**f=nnnnnn.n**

NOTE : All messages returned by TUNICS are terminated by "↵", ">" and "space" sent together.

ANNEXE D : SUMMARY OF IEEE CONTROL COMMANDS

Protocol

The following rules must be observed for the messages sent to TUNICS from the bus controller :

- If a message contains several instructions, instructions should be separated by ";" characters.
- Each message must be terminated (1) by the character LF (ASCII 10), or (2) by activating the EOI line of the bus, or (3) by both together.
- Before sending a new message to, or reading an answer from TUNICS, the controller should check that the "status word" answered by TUNICS to a serial poll corresponds to previous actions. Otherwise, errors may occur due to lack of synchronization between controller and TUNICS.

Instructions

Command	*Action*	*TUNICS response may set/clear status bits #*
I=nn.n	Sets diode laser current level (mA)	**0**
P=nn.nn	Sets power output level (mW mode active)	**0 , 3**
P=(±)nn.nn	Sets power output level (dBm mode active)	**0 , 3**
L=nnnn.nnn	Sets emission wavelength (nm)	**0 , 3**
f=nnnnnn.n	Sets emission frequency (GHz)	**0 , 3**
FSCL=nn.n	Fine Scannig mode in picometer	**0**
FSCF=n.nn	Fine Scanning mode in GHz	**0**
Smin=nnnn.nn	Sets lower scan wavelength limit (nm)	**0**
Smax=nnnn.nn	Sets upper scan wavelength limit (nm)	**0**
Step=nn.nnn	Sets scan step value (nm)	**0**
Stime=n.n	Sets scan step time (s)	**0**
I ?	Requests present current level (mA) answer format : **I=nn.n**	**0 , 4**
P ?	Requests present power output level answer format : **P=nn.nn** (mW unit active) answer format : **P=±nn.nn** (dBm unit active)	**0 , 4**
L ?	Requests present emission wavelength (nm) answer format : **L=nnnn.nnn**	**0 , 4**

f ?	Requests present emission frequency (GHz) answer format : **f=nnnnnn.n**	**0 , 4**
APCON	Switches system to constant power mode	**0 , 3**
APCOFF	Switches system to constant current mode	**0 , 3**
M W	Sets power unit to mW	**0**
DBM	Sets power unit to dBm	**0**
SCAN	Initiates scan	**0 , 3 , 7**
	(At termination of scan)	**0 , 7**
STOP	Terminates scan in progress	**0 , 7**
***SRE=nnn**	Sets automatic service request (SRQ) mask	**0**
GPAD=nn	Changes the GPIB address	**0**
ENABLE	Enables laser output	**0**
DISABLE	Disables laser output	**0**

Status Word

Bit No.	*Code Name*	*Significance when Bit = 1*
7 (MSB)	SCANNING	Wavelength scan in progress.
6	SRQ	TUNICS requests service from the bus controller.
5	(none)	(for future use)
4	MAV	The parameter value requested by the controller is now available for reading.
3	LIM	The laser current has reached its maximum upper limit (this occurs in the APC mode if the set power exceeds TUNICS' capability at the wavelength of operation).
2	ERRV	The last parameter value received from the controller is outside the incorrectly formatted.
1	ERRC	The last instruction received from the controller is incorrect.
0	OPC	TUNICS has executed all received instructions, and motor is at rest.