CLAS12-NOTE 2020-001

Hall B Spiral Raster - User's Manual

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5 February 2020

1. Introduction

The beam rastering system for Hall B polarized targets is shown in figure 1. The electron beam is deflected by the first X-Y set of magnets and then made perpendicular to the target by the second set, akin to a collimated beam. One power supply feeds both X magnets arranged such that the magnetic fields are 180^0 out of phase; the Y magnets have a similar arrangement.

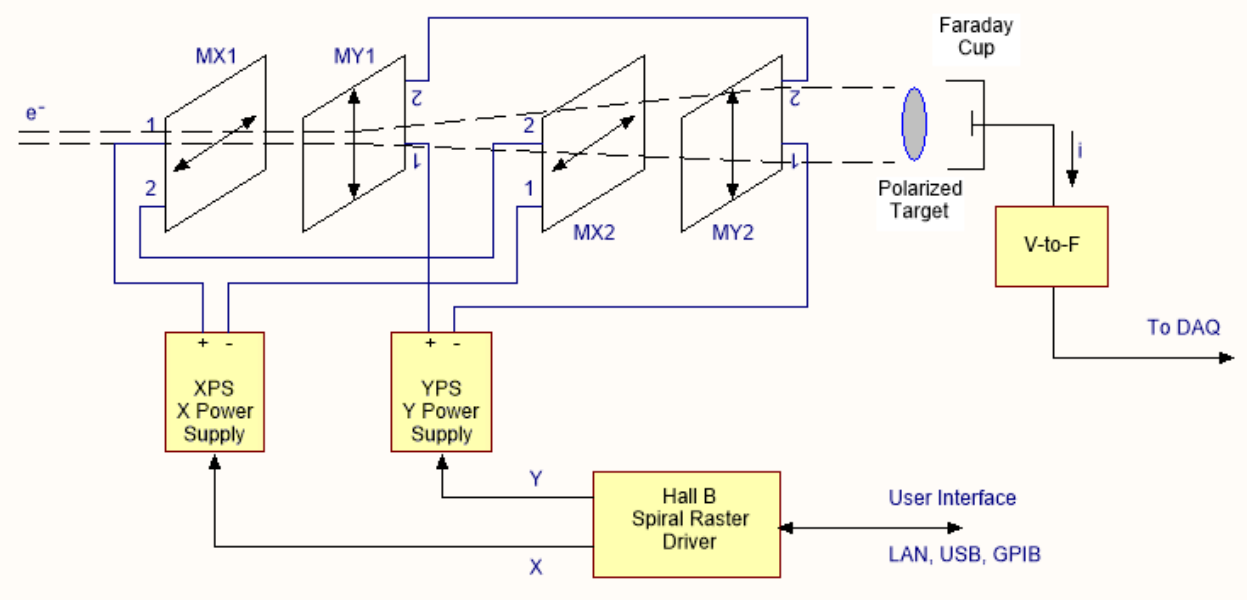


Figure 1 – Hall B Spiral Raster System Concept

The Faraday Cup provides the means for measuring total beam current by feeding a Voltage-to-Frequency (V-to-F) converter. Information from this module may be employed by the user to effect changes to the raster system or to change beam conditions.

The spiral raster driver outputs X and Y signals, which are fed to the bipolar power supplies. The characteristics of these signals depend on the raster pattern and on user settings. The size and position of the spiral pattern and the rastering speed of the beam on the target are user programmable via LAN, USB or GPIB.

CLAS-NOTE-2019-002 [1] provides detailed information about the Hall B spiral raster system implementation and signal generation. This manual provides guidelines for controlling the raster driver via the LAN interface.

The raster driver is implemented with the Keysight 33522B dual channel, arbitrary waveform generator. Refer to the Operating and Service Guide for information on the operation and programming of the unit, available from Keysight at https://literature.cdn.keysight.com/litweb/pdf/33500-90901.pdf?id=2197440. This guide also includes a SCPI Programming Reference section. Additional support is available from the Keysight website [2], [3].

2. Connections

2.1 Experimental Setup

Connect the raster driver as follows (fig. 2), using RG58 type coaxial cables:

Keysight 33522B	Danfysik 529 Power Supply
CH1	X magnets
CH2	Y magnets

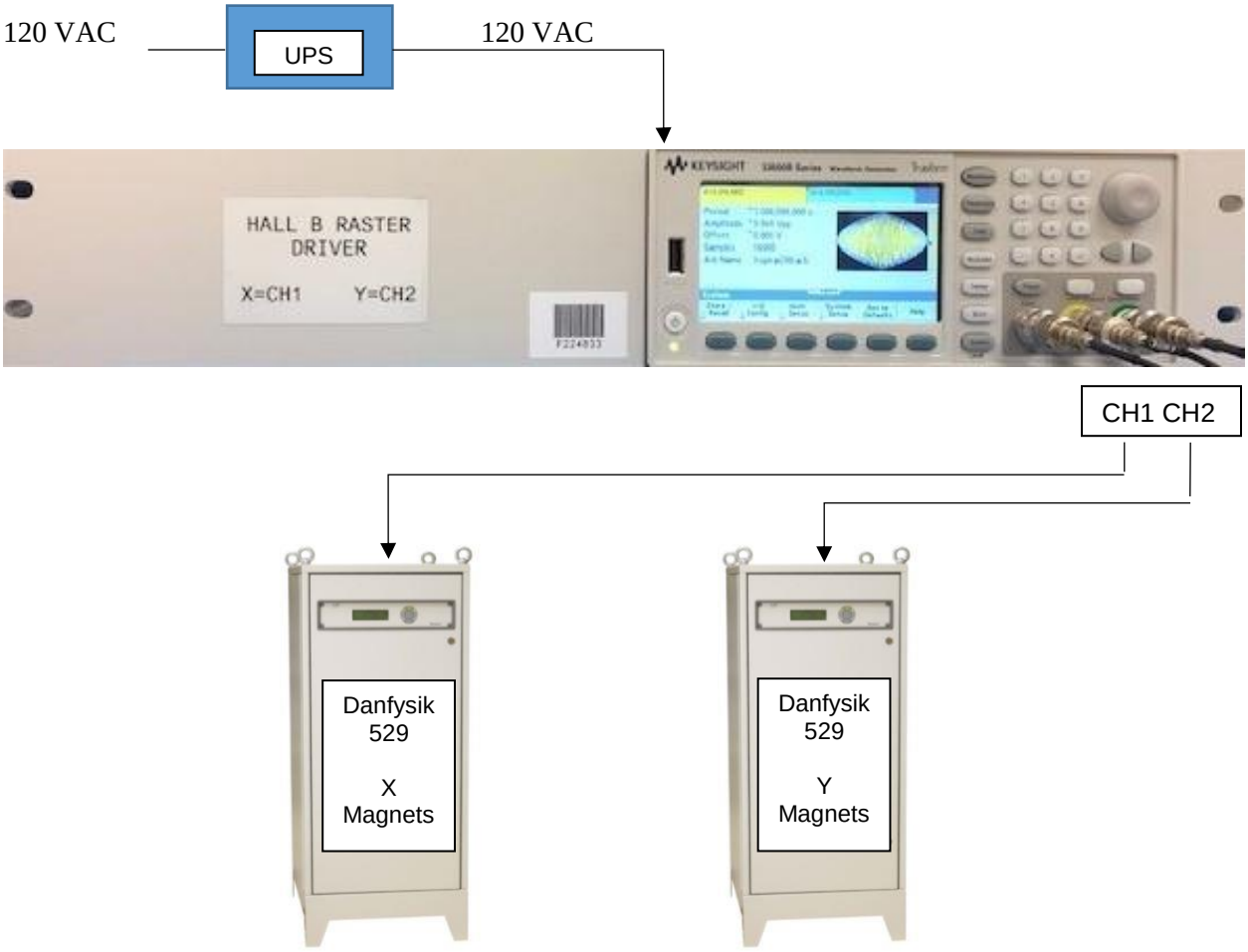


Figure 2 – Setup

The Keysight 33522B recovers from an AC power interruption into the default factory setting and it will need to be re-configured, remotely or locally, for spiral raster operation. It is recommended that a UPS be used to ensure continued and reliable operation.

2.2 Waveform Diagnostics Setup

Observation of the spiral pattern can be accomplished by connecting the raster driver to an oscilloscope, as shown in fig. 3, using coaxial cables:

Keysight 33522B	Scope Input	Note
CH1	CH1	X waveform
CH2	CH2	Y waveform
SYNC	CH3	Trigger

The scope should be set as follows:

Inputs 50 Ohm termination
Trigger CH3 at 50% threshold.
Vertical Scale 1 V
Horizontal Scale 1 s
Display Format X/Y

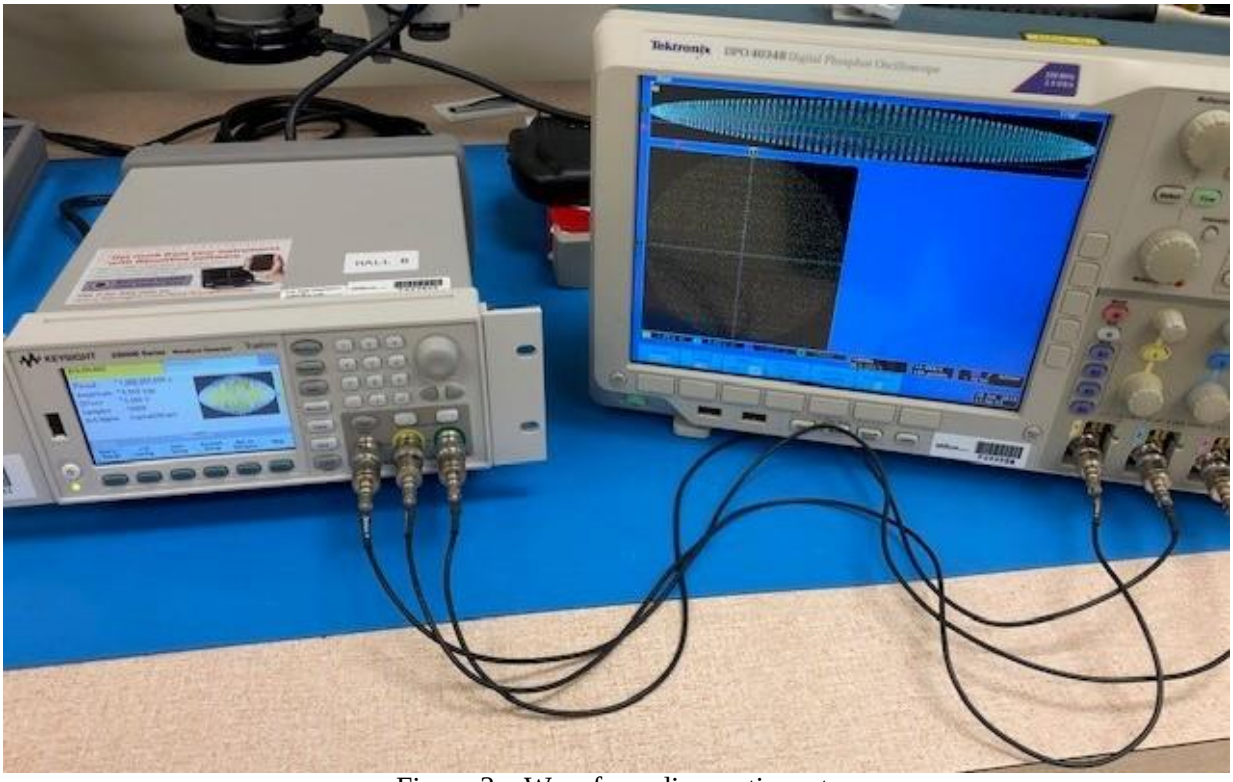


Figure 3 – Waveform diagnostics setup

The scope display of fig. 4 shows the X and Y waveforms (top) for a full cycle time of 1 s and the corresponding spiral pattern (bottom, left) at the maximum amplitude of ±5 V or 10 Vpp. This would be the result of a perfectly centered beam on the target, with the beam optics describing a spiral pattern calibrated for an outer radius of 1 cm.

Similarly, the scope display of fig. 5 shows the spiral pattern for a full cycle time of 1 s at an amplitude of ±2 V or 4 Vpp, centered at X=+2 V and Y=-2 V, corresponding to a pattern on the target with a radius of 4 mm, offset by +4 mm on X and -4 mm on Y.

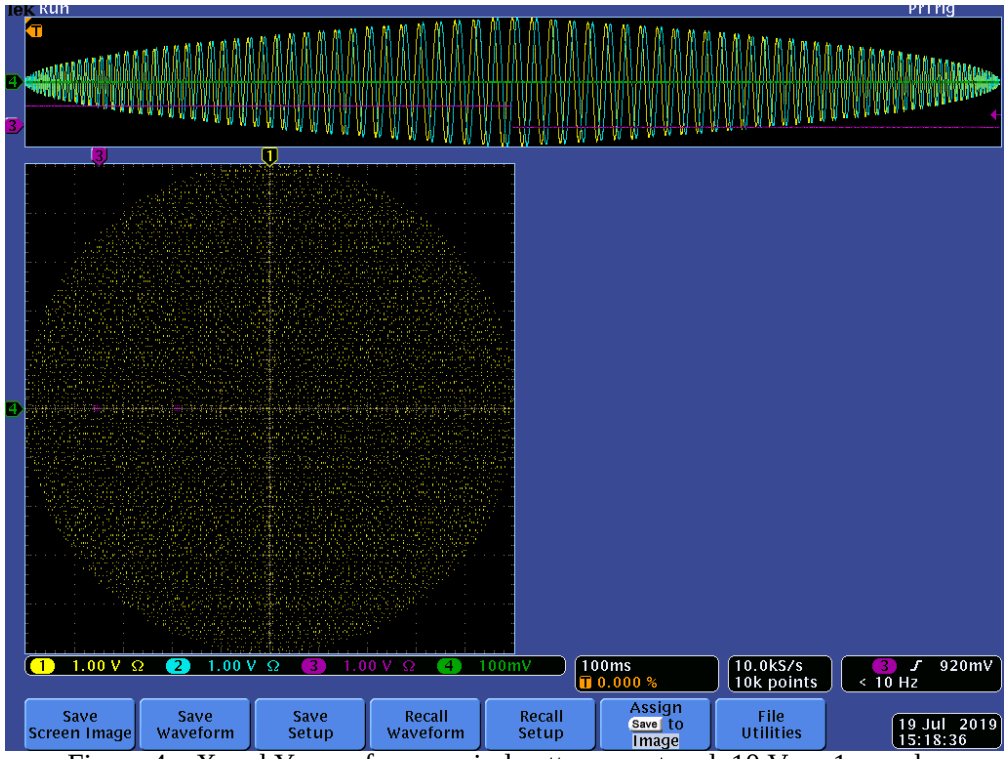


Figure 4 – X and Y waveforms, spiral pattern: centered, 10 Vpp, 1 s cycle.

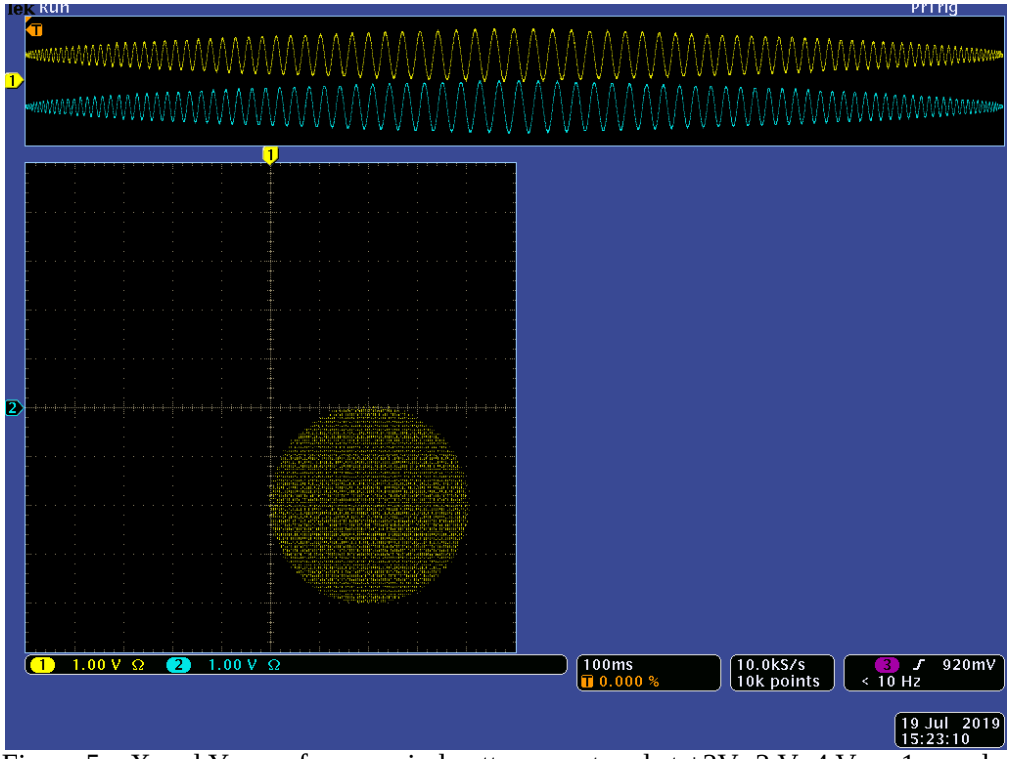


Figure 5 – X and Y waveforms, spiral pattern: centered at +2V,-2 V, 4 Vpp, 1 s cycle.

The Danfysik 529 bipolar power supply has a maximum signal input rating of ±5 V, which results in a maximum output current supply of ±240 A. The raster driver outputs of the Keysight 33522B conform to this requirement so that the combination of signal amplitude and offset are within the ±5 V envelope. The size of the pattern and its shape on the target will depend on the proper alignment of the beam optics. Per design requirements, the magnets should be arranged so as to yield a pattern size of 1 cm for ±5 V excitation and centered on the target.

3. Controls

The Keysight 33522B can be controlled from the front panel or remotely via LAN, USB or GPIB. For remote control, the instrument uses Standard Commands for Programmable Instruments (SCPI) programming language.

3.1 Remote Control

The Keysight 33522B has a built-in Web Interface which can be used over LAN for remote instrument access and control via a Java-enabled Web browser, e.g. Microsoft Internet Explorer. The procedures outlined in this manual utilize a PC, which requires a crossover Ethernet cable; connections to routers or switches requires standard CAT5 Ethernet cables. Note that the structure of the SCPI commands described below apply to any of the remote interfaces (LAN, USB or GPIB).

1. Connect the Ethernet cable (crossover Ethernet cable for connection to a PC).
2. Turn on the Keysight 33522B and allow a few minutes for the instrument to set its default factory configuration.
3. Open the Web browser and enter the unit's IP address or hostname in the address field. The factory default IP address of the Keysight 33522B is ***http://169.254.5.21***.

The browser display should look as in fig. 6.

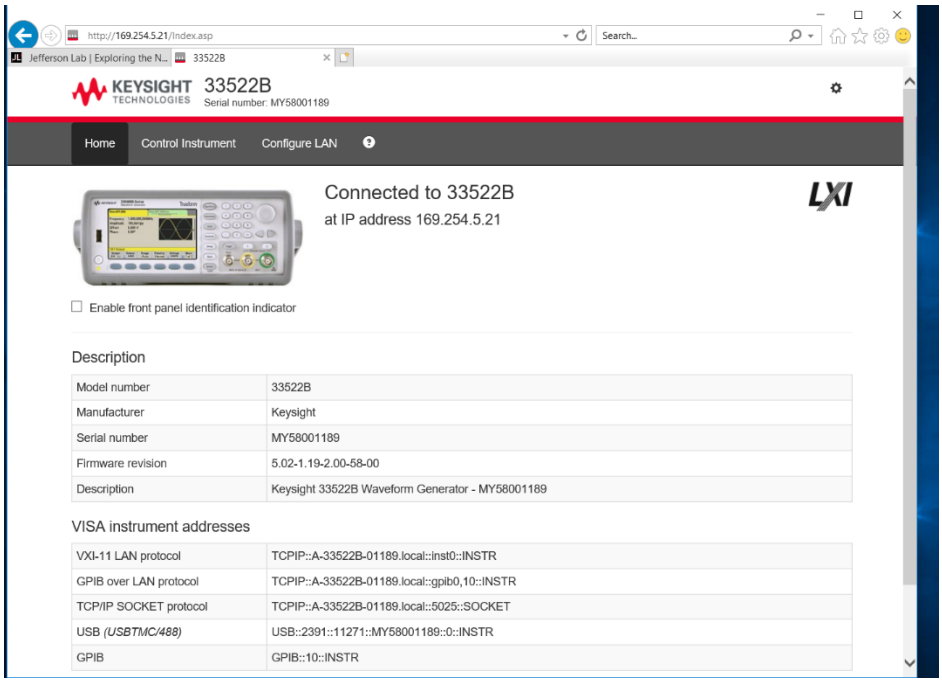


Figure 6 – The Web browser after establishing connection.

Click on the ***Control Instrument*** button and then click on the ***Use Instrument IO*** button, as shown in fig. 7.

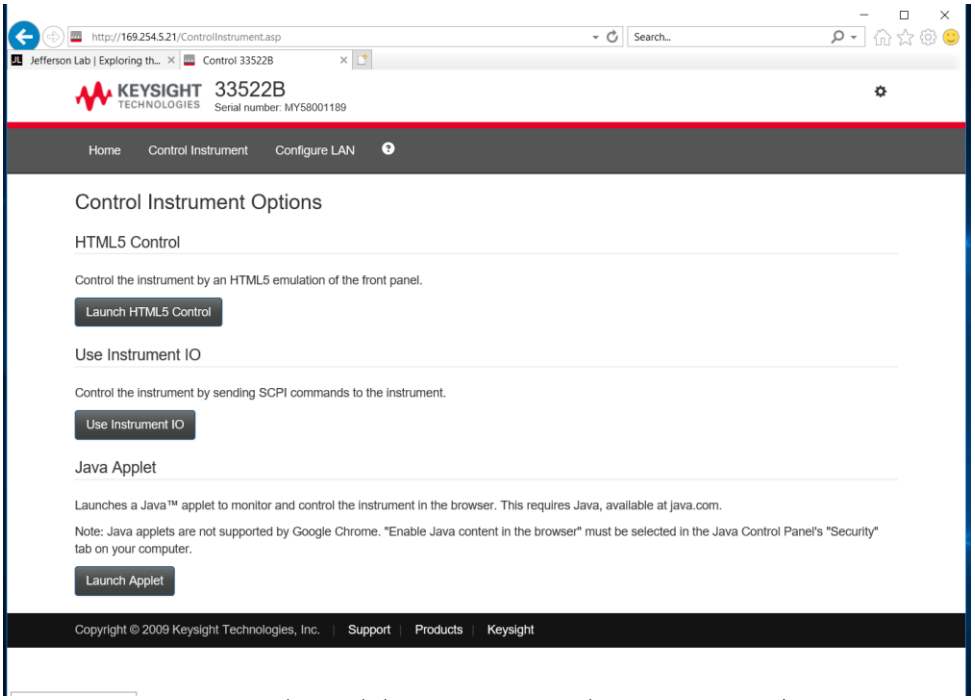


Figure 7 – The Web browser's Control Instrument Options.

The ***Interactive IO*** screen is shown in fig. 8: enter a command in the ***Command*** line and click the ***Execute*** button. The ***Response history*** section will show the commands that were sent to and responses read from the instrument.

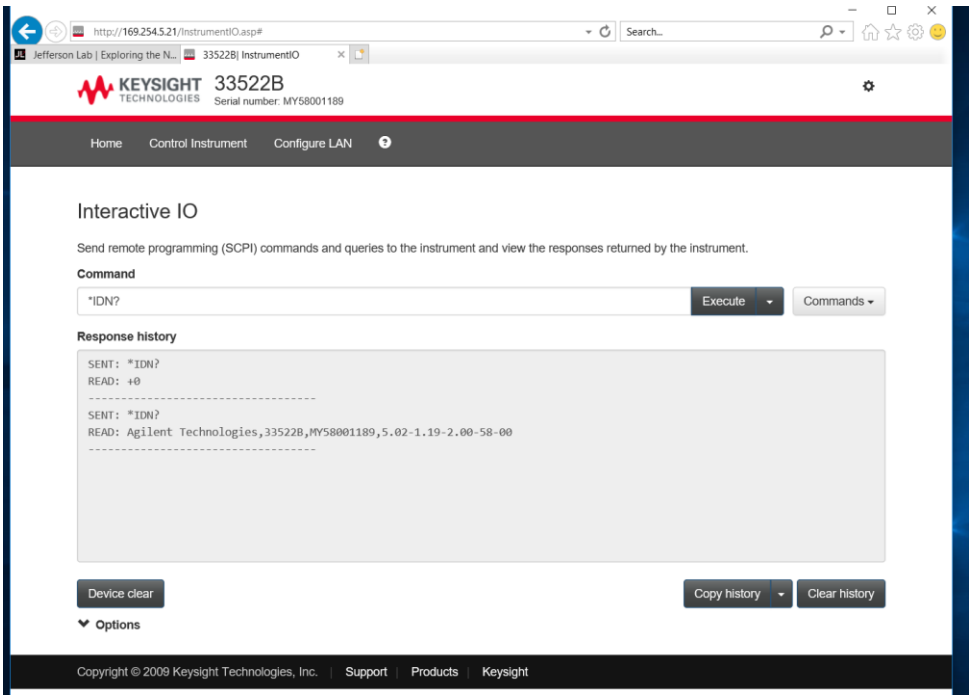


Figure 8 – The Web browser's Interactive IO.

The example shown in fig. 8 uses the command ***IDN?** to query the instrument identification. A short list of standard commands is available under the ***Commands*** button in the Web browser ***Interactive IO*** screen.

LAN configuration settings can be accessed via the ***Configure LAN*** button at the top of the Web browser screen.

3.2 Raster Configuration & Control

The nominal raster configuration applies to a beam with a diameter of 200 µm FWHM; additional configurations for beam diameters of 100 µm FWHM and 400 µm FWHM are also available. All the raster waveform files are stored in the instrument internal drive and sub-directory *RASTER* (INT:\RASTER\...) as shown in fig.6 and table 1.

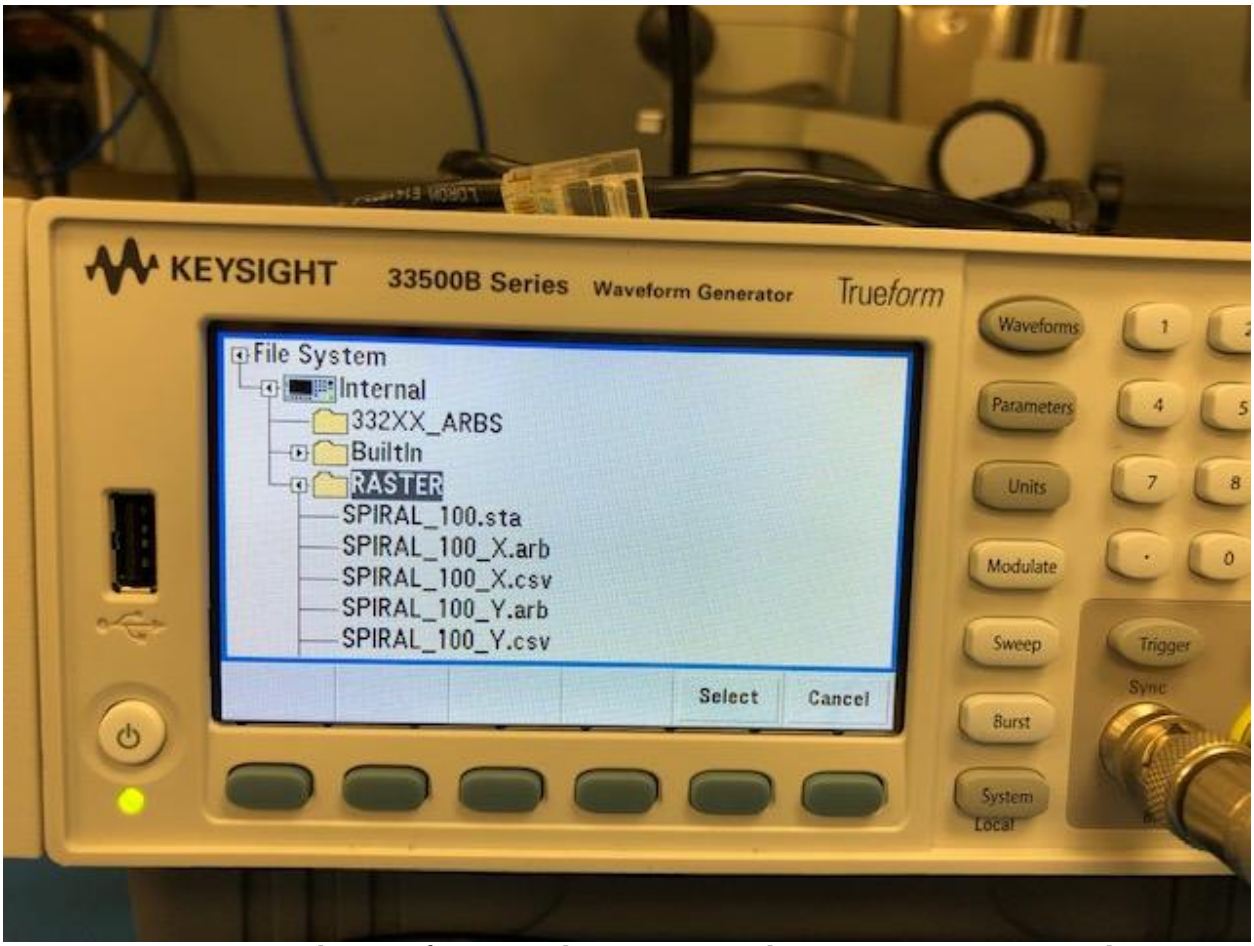


Figure 6 – X and Y waveforms, spiral pattern: centered at +2V,-2 V, 4 Vpp, 1 s cycle

Table 1: Raster files stored in the Keysight 33522B (INT:\RASTER\...)

File Name	Type	Comment
		Files for 100 µm beam diameter
SPIRAL_100.sta	state	Configuration
SPIRAL_100_X.arb	CH1 (X) data	Instrument waveform data
SPIRAL_100_X.csv	CH1 (X) data	Original waveform data

SPIRAL_100_Y.arb	CH2 (Y) data	Instrument waveform data
SPIRAL_100_Y.csv	CH2 (Y) data	Original waveform data
		Files for 200 µm beam diameter
SPIRAL_200.sta	state	Configuration
SPIRAL_200_X.arb	CH1 (X) data	Instrument waveform data
SPIRAL_200_X.csv	CH1 (X) data	Original waveform data
SPIRAL_200_Y.arb	CH2 (Y) data	Instrument waveform data
SPIRAL_200_Y.csv	CH2 (Y) data	Original waveform data
		Files for 400 µm beam diameter
SPIRAL_400.sta	state	Configuration
SPIRAL_400_X.arb	CH1 (X) data	Instrument waveform data
SPIRAL_400_X.csv	CH1 (X) data	Original waveform data
SPIRAL_400_Y.arb	CH2 (Y) data	Instrument waveform data
SPIRAL_400_Y.csv	CH2 (Y) data	Original waveform data

Notes:

1. .sta state files determine the complete state of the instrument after execution. These files were saved after the instrument was setup by loading the X and Y arbitrary waveform files (.arb) and setting CH1 and CH2 synchronization, amplitude and offset levels and period.
2. .arb files (ASCII) contain the instrument operational waveform data and were created after importing the original waveform data (.csv).
3. .csv files (ASCII) contain the original waveform data. These files are not used by the instrument but are stored for consistency.

Preset instrument states are also available in non-volatile memory, in addition to the instrument state files described above, and as shown in table 2. This makes it easier to recall the instrument state remotely via SCPI commands.

Table 2: Configuration states in non-volatile memory

State	**Configuration**	**Note**
1	200 µm beam	Design default
2	100 µm beam	Optional
3	400 µm beam	Optional

The three configuration states have similar parameter settings, except for the instrument waveform data files used, table 3.

Table 3: Preset configuration parameter settings

Parameter	**Setting**	**Note**
RATE	Period = 5 s, Coupled	Cycle time of full spiral, same period for both channels.
FUNCTION	ARB, SYNChed	Arbitrary function waveforms, both channels are synchronized.
OUTPUTS	Amplitudes = 0 V Offsets = 0 V Status = OFF	Amplitudes and offsets are set at zero volts and outputs are disabled.

After power up or reset, the raster driver will be in a factory default state [4]. The following sequence of steps will bring the raster into full operation for the maximum pattern size, once LAN operation is well established:

```
A. Load
   Configuration
```

Command	Description
*RCL 1	Recall the configuration State 1 for 200 µm beam. The instrument waveform data for CH1 (X) and CH2 (Y), i.e. .arb files, will be loaded and the configuration parameters for rate, function and outputs will be set.

```
B. Set Waveform
   Amplitudes & Offsets
```

Command	Description
SOUR1:VOLT:OFFS 0	Set CH1 to an offset of 0 V, centered X pattern.
SOUR2:VOLT:OFFS 0	Set CH2 to an offset of 0 V, centered Y pattern.
SOUR1:VOLT 10	Set CH1 output to 10 Vpp for maximum X pattern size.
SOUR2:VOLT 10	Set CH2 output to 10 Vpp for maximum Y pattern size.

Note: Setting CH1 (X) to the maximum amplitude of 10 VPP will result in a message stating that the value is too high and an appropriate amplitude will be set. This amplitude differs for the various beam diameter settings and is due to the fact that the pattern on X is not symmetrical as it starts one beam radius away from the center [1], [5].

```
C. Enable Outputs
```

Command	Description
OUTP1 1	CH1 on.
OUTP2 1	CH2 on.

```
D. Verify Settings (Optional)
```

Command	Description
SOUR1:VOLT?	Query CH1 amplitude setting
SOUR2:VOLT?	Query CH2 amplitude setting
SOUR1:OFFS?	Query CH1 offset setting
SOUR2:OFFS?	Query CH2 offset setting
FUNC:ARB:PER?	Query waveform period or cycle time, in seconds.
SOUR1:RATE:COUP?	Query returns 1 if rates of channels are coupled.
MEM:STAT:NAME?	Query returns configuration state (e.g. 1 for 200 µm beam).
OUTP1?	Query returns 1 if CH1 output is on.
OUTP2?	Query returns 1 if CH2 output is on.

Examples of command sequences and usage are shown below.

Command	Description
	Disable outputs:
OUTP1 0	CH1 off.
OUTP2 0	CH2 off.
	Set Waveform Amplitudes & Offsets:
SOUR1:VOLT 0	Set CH1 output to 0 Vpp.
SOUR2:VOLT 0	Set CH2 output to 0 Vpp.
SOUR1:VOLT:OFFS 1	Set CH1 with an offset of +1 V.
SOUR2:VOLT:OFFS -2	Set CH2 with an offset of -2 V.
SOUR1:VOLT 5	Set CH1 output to 5 Vpp.
SOUR2:VOLT 5	Set CH2 output to 5 Vpp.
	Enable Outputs:
OUTP1 1	CH1 on.
OUTP2 1	CH2 on.
	To change the waveform period or cycle time:
FUNC:ARB:PER 1	Set the period to 1 s.

3.3 Commands

A - A list of the most relevant commands to use with the spiral raster is shown below:

Command	Description
SOUR[1/2]:FUNC?	Query returns waveform function (e.g. ARB).
SOUR[1/2]:VOLT <*amplitude*>	Set the amplitude of CH1 or CH2 in Vpp (0 to 10).
SOUR[1/2]:VOLT?	Query amplitude setting on CH1 or CH2.
SOUR[1/2]:VOLT:OFFS <*offset*>	Set the offset of CH1 or CH2 in V (-5 to +5).
SOUR[1/2]:VOLT:OFFS?	Query amplitude setting on CH1 or CH2.
SOUR[1/2]:FUNC:ARB:PER <*period*>	Set the period of the waveform in seconds.
SOUR[1/2]:FUNC:ARB:PER?	Query the period of the waveform.
FUNC:ARB:SYNC	Synchronize waveforms on CH1 and CH2.
FREQ:COUP <*ON/1/OFF/0*>	Enable coupling waveform frequencies or periods on CH1 and CH2.
FREQ:COUP?	Query frequency coupling state.
OUTP[1/2] <*ON/1/OFF/0*>	Enable output of CH1 or CH2.
OUTP[1/2]?	Query output state.
MEM:STAT:NAME?	Query configuration state in operation (e.g. 1).
MMEM:CAT? “INT:\RASTER”	Returns a list of all files in the internal directory RASTER.
MMEM:LOAD:DATA[1/2] “<*filename*>”	Load .arb file from internal drive for CH1 or CH2 into memory (e.g. “INT:\RASTER\ SPIRAL_200_X.arb).

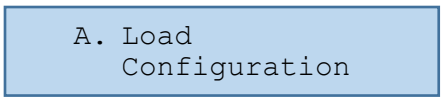
SOUR1[1/2]:FUNC:ARB "<*filename*>"	Select loaded waveform data (e.g. "INT:\RASTER\ SPIRAL_200_X.arb) for CH1 or CH2.
MMEM:LOAD:STAT "<*filename*>"	Load .sta file from internal drive (e.g. "INT:\RASTER\SPIRAL_200.sta").
DISP:UNIT:ARBR PER	Set the waveform units to seconds.
SYST:COMM:ENAB	
*CLS	Clear event registers and error queue.
*IDN?	Query instrument identification.
*RCL <*0/1/2/3/4*>	Recall instrument state.
*RST	Reset instrument to factory defaults.

B - A list of LAN configuration commands is shown below:

SYST:COMM:LAN:DHCP <*ON/1/OFF/0*>	Enable to automatically assign an IP address.
SYST:COMM:LAN:DHCP?	Query DHCP enabled state (e.g. 1).
SYST:COMM:LAN:IPAD "<*address*>"	Assign instrument IP address (e.g. "169.254.2.20") after disabling DHCP.
SYST:COMM:LAN:IPAD?	Query IP address.
SYST:COMM:LAN:MAC?	Query MAC address.
SYST:COMM:LAN:SMAS "<*mask*>"	Assign instrument subnet mask (e.g. "255.255.0.0").
SYST:COMM:LAN:SMAS?	Query subnet mask.
SYST:COMM:LAN:GAT "<*address*>"	Assign gateway address, IP address by default.
SYST:COMM:LAN:GAT?	Query gateway address.
SYST:COMM:LAN:HOST "<*name*>"	Assign hostname of instrument.
SYST:COMM:LAN:HOST?	Query hostname.
SYST:COMM:LAN:DNS[1/2] "<*address*>"	Assign DNS.
SYST:COMM:LAN:UPD	Update LAN setting. This must be issued after a LAN setting is or a group of settings are changed.

3.4 Front Panel Control

The spiral raster can also be controlled locally via the front panel keys. If the instrument has been in remote mode, press the *SYSTEM* key until local control is established.



Press Key	**Comment**
SYSTEM	
STORE/RECALL	
RECALL STATE	In file system, scroll down (rotary knob) to folder RASTER, press right arrow button and then scroll down to choose instrument state file.
SELECT	Click SPIRAL_200.sta for the 200 µm beam configuration.

B. Set Waveform Amplitudes & Offsets

Press Key	Comment
CH1	Select CH1 (X).
PARAMETERS	
OFFSET	Use keypad to enter value: 0, centered X pattern.
V	Select V for Volts.
CH2	Select CH2 (Y).
PARAMETERS	
OFFSET	Use keypad to enter value: 0, centered Y pattern.
V	Select V for Volts.
CH1	Select CH1 (X) display.
PARAMETERS	
AMPLITUDE	Use keypad to enter value: 10, for maximum X pattern size.
V	Select Vpp for Volts pp.
CH2	Select CH2 (Y) display.
PARAMETERS	
AMPLITUDE	Use keypad to enter value: 10, for maximum Y pattern size.
V	Select Vpp for Volts pp.

Note: Setting CH1 (X) to the maximum amplitude of 10 VPP will result in a message stating that the value is too high and an appropriate amplitude will be set. This amplitude differs for the various beam diameter settings and is due to the fact that the pattern on X is not symmetrical as it starts one beam radius away from the center [1], [5].

C. Enable Outputs

Press Key	Comment
CH1	Select CH1 (X).
OUTPUT OFF/ON	Press to toggle ON.
CH2	Select CH2 (Y).
OUTPUT OFF/ON	Press to toggle ON.

D. Verify Settings (Optional)

Press Key	Comment
CH1	Select CH1 (X). The display shows the Period (s), Amplitude (Vpp), Offset (V), Samples (samples per cycle) Arb Name (e.g. SPIRAL_200_X.arb. The * preceding the period value indicates that the periods on both channels are coupled and adjusted to the same value. The *OUTPUT OFF/ON* key displays if the output status of the channel; the center portion of the *CH1* key is illuminated if the channel is ON.
CH2	Select CH2 (Y). The display shows the Period (s), Amplitude (Vpp), Offset (V), Samples (samples per cycle) Arb Name (e.g. SPIRAL_200_Y.arb. The * preceding the period value indicates that the periods on both channels are coupled and adjusted to the same value. The *OUTPUT OFF/ON* key displays if the output status of the channel; the center portion of the *CH1* key is illuminated if the channel is ON.

Examples of command sequences and usage are shown below.

Press Key	**Comment**
	Disable outputs:
CH1	Select CH1 (X).
OUTPUT OFF/ON	Press to toggle OFF.
CH2	Select CH2 (Y).
OUTPUT OFF/ON	Press to toggle OFF.
	Set Waveform Amplitudes & Offsets:
CH1	Select CH1 (X).
PARAMETERS	
AMPLITUDE	Use keypad to enter value: 0.
V	Select V for Volts pp.
OFFSET	Use keypad to enter 1 for X pattern offset.
V	Select V for Volts.
AMPLITUDE	Use keypad to enter value: 5.
V	Select V for Volts pp.
CH2	Select CH2 (Y).
PARAMETERS	
AMPLITUDE	Use keypad to enter value: 0.
V	Select V for Volts pp.
OFFSET	Use keypad to enter -2 for Y pattern offset.
V	Select V for Volts.
AMPLITUDE	Use keypad to enter value: 5.
V	Select V for Volts pp.
	Enable Outputs:
CH1	Select CH1 (X).
OUTPUT OFF/ON	Press to toggle ON.
CH2	Select CH2 (Y).
OUTPUT OFF/ON	Press to toggle ON.
	To change the waveform period or cycle time:
CH1	Select CH1 (X).
PARAMETERS	
PERIOD	Use keypad to enter 1.
SECONDS	Select seconds.

[1] “Spiral Raster for Hall B Polarized Targets”, FJ Barbosa, JLab, 30 July 2019.

[2] Instrument Drivers:
https://www.keysight.com/main/software.jspx?ckey=1937336&lc=eng&cc=US&nid=-536902257.1026944&id=1937336 .

[3] IO Libraries Suite:
https://www.keysight.com/en/pd-1985909/io-libraries-suite?nid=-33330.977662.00&cc=US&lc=eng&cmpid=zzfindiosuite .

[4] Reset to the factory default state prior to changing configuration states: *SYSTEM* and *Set To Defaults* (front panel control) or *RST (remote control).

[5] The maximum amplitude values for CH1 (X) are 9.975 VPP (100 µm), 9.949 VPP (200 µm) and 9.897 VPP (400 µm).