Klystron modulator Factory Acceptance Test Report

TR000024 Scandinova K100 FAT Protocol SN M1700-2

Model: K100

Serial No: M1700-2

1 Introduction

1.1 Identification of document

This document is the factory acceptance test (FAT) protocol for the ScandiNova RF Unit.

1.2 Identification of main unit(s) during test

The table below shows model and serial number(s) for main unit(s) during test.

Unit	Model	Serial no
Modulator	K100	M1700-2
Klystron	E3772A,A	19D100
Solenoid	VT-68934	19D022

2 Attachments

☒Appendix 1 (List of instruments) completed. ☒Passed

☒Appendix 2 (Oscilloscope figures) completed. ☒Passed

3 Test with klystron

3.1 Calibrations and interlock tests in STANDBY mode

☒Filament current set and read calibrated. ☒Passed

☒Filament voltage read calibrated. ☒Passed

☒Filament voltage limit potentiometer adjusted. ☒Passed

☒Filament current interlock tested. ☒Passed

FilCurrHlim: 12.9

FilCurrLlim: 10.9

☒Filament voltage interlock tested. ☒Passed

FilVoltHlim: 15.0

FilVoltLlim: 12.5

☒Klystron collector cooling water flow interlocks tested. ☒Passed

☒Klystron body water flow interlock tested. ☒Passed

☒Solenoid water flow interlock tested. ☒Passed

☒Klystron Ion pump set point tested, interlock trip level 1.6e-7 mBar.
☒Passed

☒FilamentBlockingTime set Set value …2700……

3.2 Calibrations and interlock tests in HV mode

☒SPS 1, current and voltage, set and read calibrated. ☒Passed

☒SPS 2, current and voltage, set and read calibrated. ☒Passed

☒SPS 1 current interlock tested. ☒Passed

SPS1CurrHlim: 34
SPS1CurrLlim: 28

☒SPS 1 voltage interlock tested. ☒Passed

SPS1VoltHlim: 120
SPS1VoltLlim: 90

☒SPS 2 current interlock tested. ☒Passed

SPS2CurrHlim: 13
SPS2CurrLlim: 11

☒SPS 2 voltage interlock tested. ☒Passed

SPS2VoltHlim: 1.5
SPS2VoltLlim: 0.2

3.3 Calibrations and interlock tests in TRIG mode

Read value interlocks

☒CT read interlock tested, ☒Passed
High Limit: 117A

☒CVD read interlock tested, ☒Passed
High Limit: 167kV

☒CT arc interlock tested, ☒Passed
Trip Level : 122A

☒Klystron vacuum interlock, ☒Passed
TripLevel: 1600µA

Set value limits

☒Plswth set limit ☒Passed
High Limit: 8µs

☒Trig PRF set limit, ☒Passed
High Limit: 200Hz

☒Filament current set limit, ☒Passed
High Limit: 15A

4 Performance measurements

4.1 Mains power measurements

Three phase power input

Parameter	Required value	Measured value	OK	Notes/Location of measurement	Instrument ID	Signature
Phase – phase voltage [VAC]	L1: L2: L3:	402 403 405	OK	Measured running with 18.5kW average output into dummy load (i.e. full output power but no solenoids and low filament current).	0210	MKM
Line frequency [Hz]		50	OK		0210	MKM
Three phase line current [A]	45	39 34 37	OK		0210	MKM
Power [kVA]		25.6	OK		0210	MKM
Cos φ		0.98	OK		0210	MKM

Single phase power input

Parameter	Required value	Measured value	OK	Notes/Location of measurement	Instrument ID	Signature
Phase – phase voltage [VAC]	L1:	231	OK	Measured running with 18.5kW average output into dummy load (i.e. full output power but no solenoids and low filament current).	0179	MKM
Line frequency [Hz]		50	OK		0179	MKM
Single phase line current [A]	6	1.88	OK		0234	MKM

4.2 Performance test

Parameter	Required value	Measured value	OK	Notes/Location of measurement	Instrument ID	Signature
Output Pulse Voltage [kV]	*Min: 80 *Max: 160	[150] 157	Y	[Using resistive load] Klystron nameplate	Zscope1	[MKM] RL
Output Pulse Current [A]	*Min: 40 *Max: 120	[100] 114	Y	[Using resistive load] Klystron nameplate	0251 Zscope1	[MKM] RL
Average Power to klystron [kW]		[18.5]	Y	[Using resistive load]		[MKM]
Peak Beam Power [MW]		17.9	Y	Calculated		RL
Pulse top flatness (dV) [%] within µs	Max: 5%	2.28%	Y	Modulator Pulse Width set to 5.5 µ	Zscope1	RL
Pulse Repetition Frequency [Hz]	Max: 50 Hz		Y	Internal trigger at 50 Hz; External at 30 Hz		RL
Pulse length (top) [µs]	Max: 5 µs	4.0 µs	Y	Modulator Pulse Width set to 5.5 µs	Zscope1	RL
Pulse to pulse Amplitude Stability [%]	Max: 0.1%	<6.5e-4*	Y	LTI cannot directly measure – used ebeam energy stability*		RL
Rate of rise [kV/ µs] Measured at 50% of peak voltage	Min: 100 Max: 150	150	Y		Zscope1	RL

Parameter	Required value	Measured value	OK	Notes/Location of measurement	Instrument ID	Signature
Rate of fall [kV/ µs] Measured at 50% of peak voltage	Min: 100 Max: 150	110	Y		Zscope1	RL
Klystron filament DC current [A]		12.5	Y		internal	RL
Klystron filament DC voltage [V]		15	Y		internal	RL

Note: The calibration factor (X) is the quote between the calculated value of the high voltage (according to klystron perveance) and measured CVD (Capacitive voltage divider) voltage in the modulator. *) Range for pulse tuning.

*Electron beam energy stability was measured during the RF Electron Source test (12/22/20-01/22/21) with the M1700-2 (this modulator) along with the M1700-3. Including injector laser timing stability, the calculated Pulse to Pulse Amplitude Stability of each modulator < 0.065%, which meets specification as listed in GD000005 Scandinova K100 Modulator System Specification.

4.3 Long run test

Below are the settings for the RF Electron Source test, in which the modulator logged over 100 hours of triggered operation (30Hz)

Run-Time meter ended at 129.0 hours 1/22/2021

4.3.1 Settings for long run test

CCPS Set [V]	SPS 1 Set [A]	SPS 2 Set [A]	Flow 1 [l/m]	Flow 2 [l/m]	Flow 3 [l/m]	Flow 4 [l/m]	Flow 5 [l/m]		
1220	32.1	N/A	7.4	7.6	10.8	27.3	11.1		

4.3.2 Long run log

	Time	Osc picture no.	Signature
Hour 0	10:37	Pic.10	MKM
Hour 1	11:48	Pic.11	MKM
Hour 2	12:45	Pic.12	MKM
Hour 3	13:55	Pic.13	MKM
Hour 4	14:38	Pic.14	MKM

4.4 Specification of tuning elements

Type of element	Coil diam	Coil no of turns	Resistor resistance	Quantity	Comments
L+(L//R)	20	3	94mOhm	12	Series coil: 4 turns, 20mm diam

5 Personal Safety test

5.1 Bleeder circuit test

Requested time	Measured time	Passed	Signature
3 sec	0.74 sec	OK	MKM

6 Remote control test

6.1 Remote operation

☒Modulator remote connection tested, type of protocol Teamviewer ☒Passed

7 Special customer require tests

8 Finalizing test

☒Soft backup taken ☒Passed

Date of factory acceptance test: 2019-12-02

Start of long run test: 10:37

End of long run test: 14:38

Date of site acceptance test: 2021-01-22……..

FAT Approved by:

Customer Signature:

Name

Rod Loewen, CTO

Company Name

Lyncean Technologies, Inc.

ScandiNova Signature:

Project Manager

Mikael Lindholm

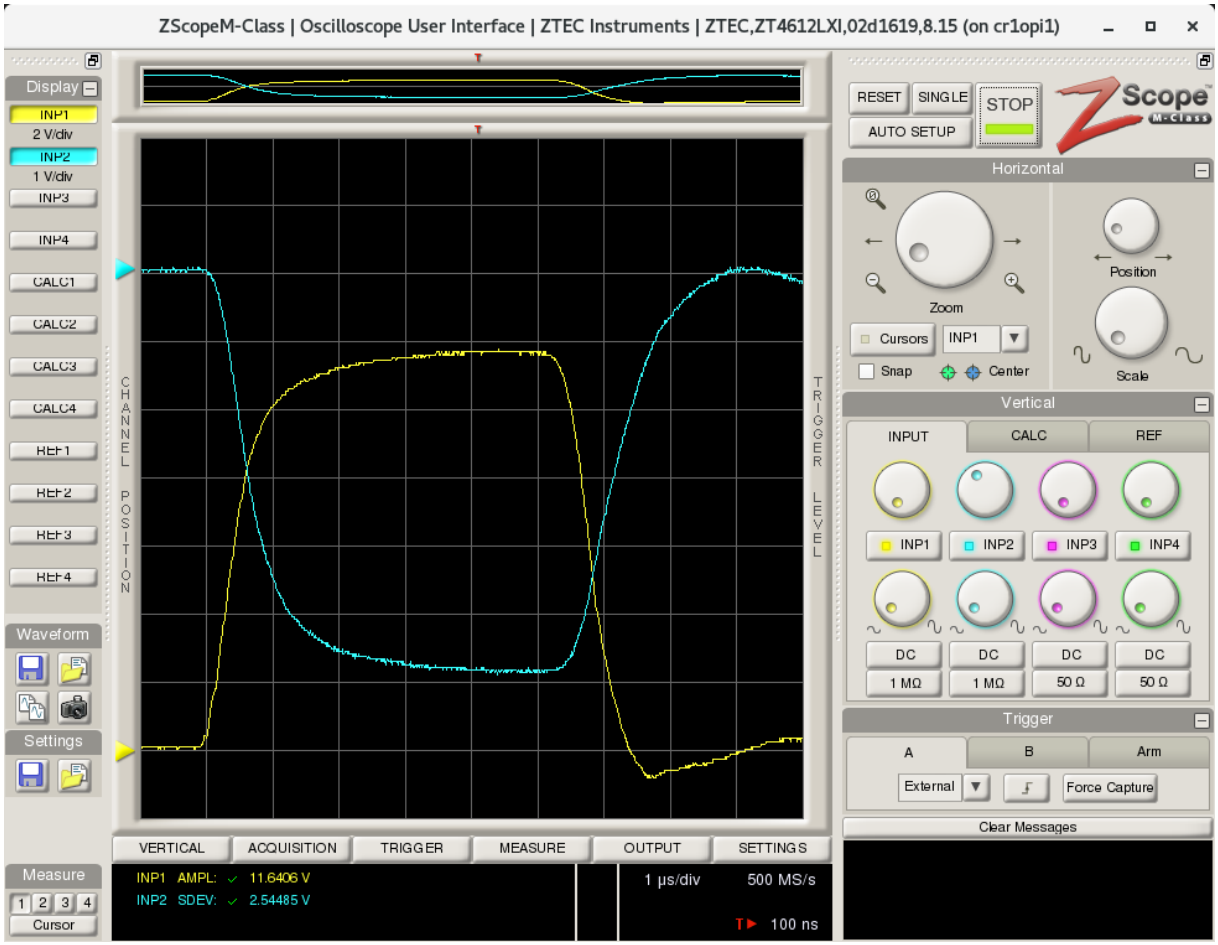
9 Attachments

9.1 Appendix 1, List of Instruments

SCN Inv no	Type:	Manufacturer:	Manufacturer S/N	Model	Status	Calibrated	Next calibration
0210	Power Meter	Fluke	3893118	435sII	OK	2019-03-06	2020-03
0051	Multimeter	Fluke	88230028	175	OK	2019-01-23	2020-01
0179	Multimeter	Fluke	34340155	179	OK	2019-01-15	2020-01
0234	Clamp meter	Beha	160800746	AMP-25-EUR	OK	2018-11	2019-11
0251	Oscilloscope	LeCroy	LCRY4207N21789	8104-MS	OK	2019-10-24	2020-10
	Differential Amplifier	LeCroy		DA1855A			

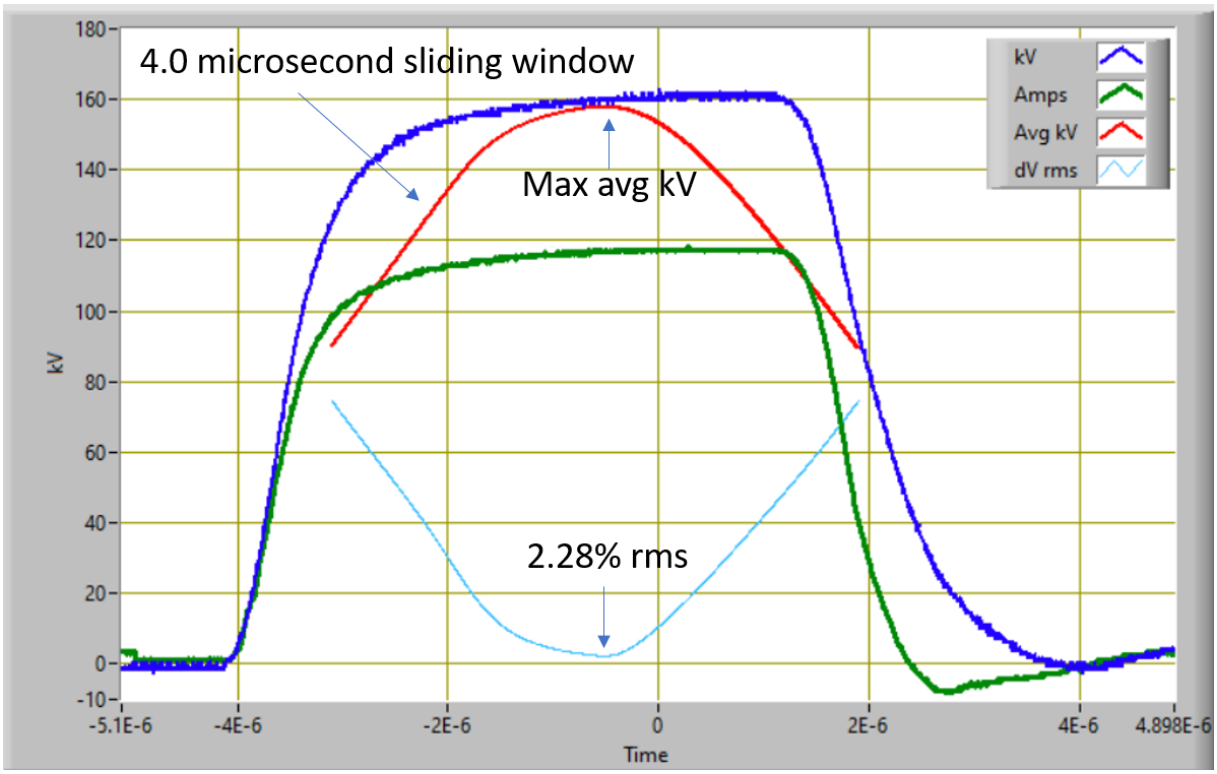
9.2 Appendix 2, Oscilloscope Records

Pic 1: Klystron current 0.1V/A (ch1 yellow) and Klystron voltage (ch2 blue)



Pic 2:

Pulse top flatness % Measured with 4.0 microsecond window, 2.28%



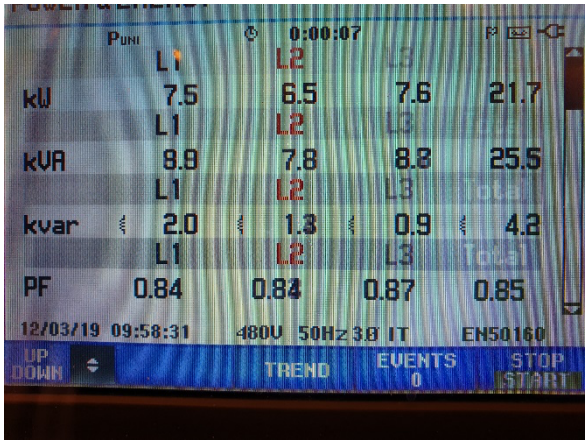
Pic 4: N/A

µs Pulse to pulse stability %

Rate of rise kV/µs calculated from above waveform to be 150kV/µs

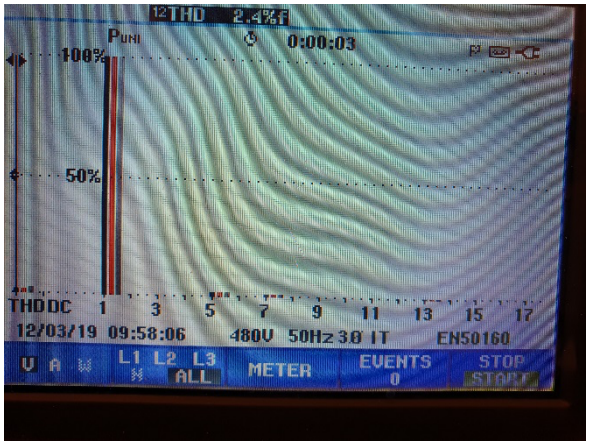
Rate of fall kV/µs calculated from above waveform to be 109kV/µs

Pic 7:



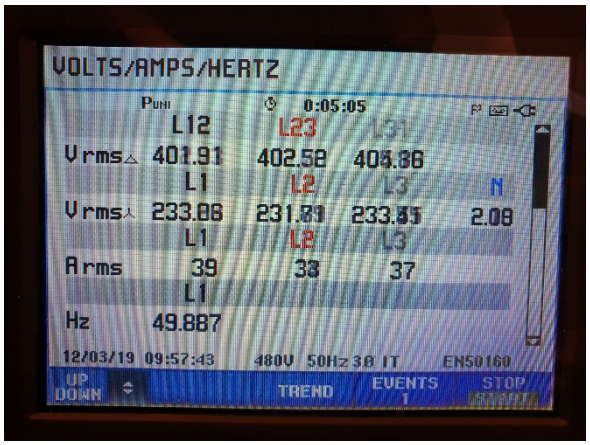
Three phase power and energy

Pic 8:



Harmonics

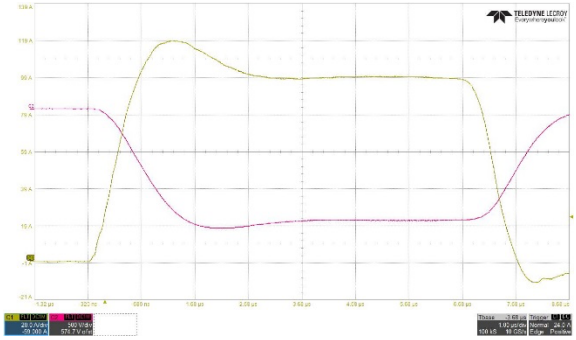
Pic 9:



Voltage, Current and Frequency

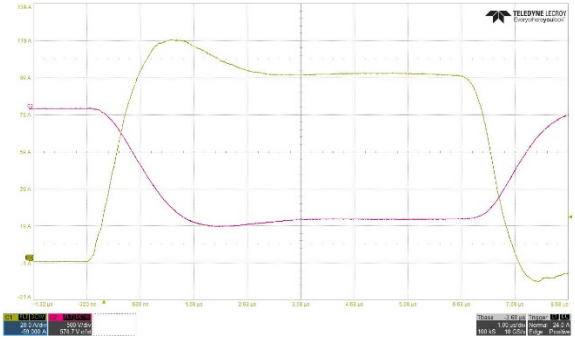
Long Run Test

Pic 10:



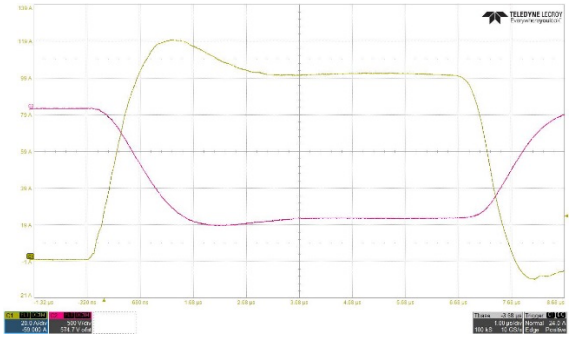
Hour 0

Pic 11:



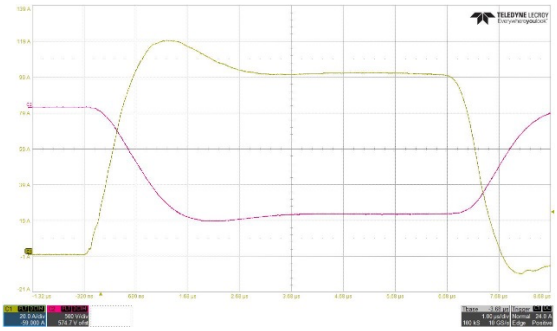
Hour 1

Pic 12:



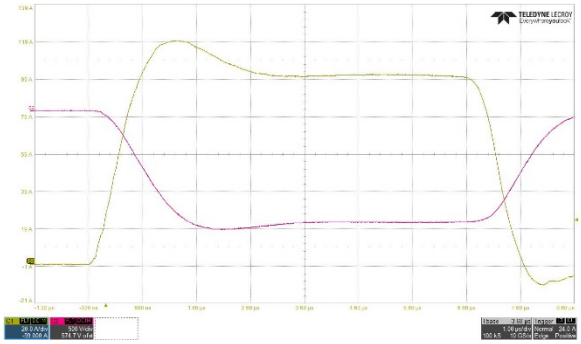
Hour 2

Pic 13:



Hour 3

Pic 14:



Hour 4