HTS instrumentation Report

Report on instrumentation activities on HTS insert in 927 lab.

- **HTS spot heater fabrication**

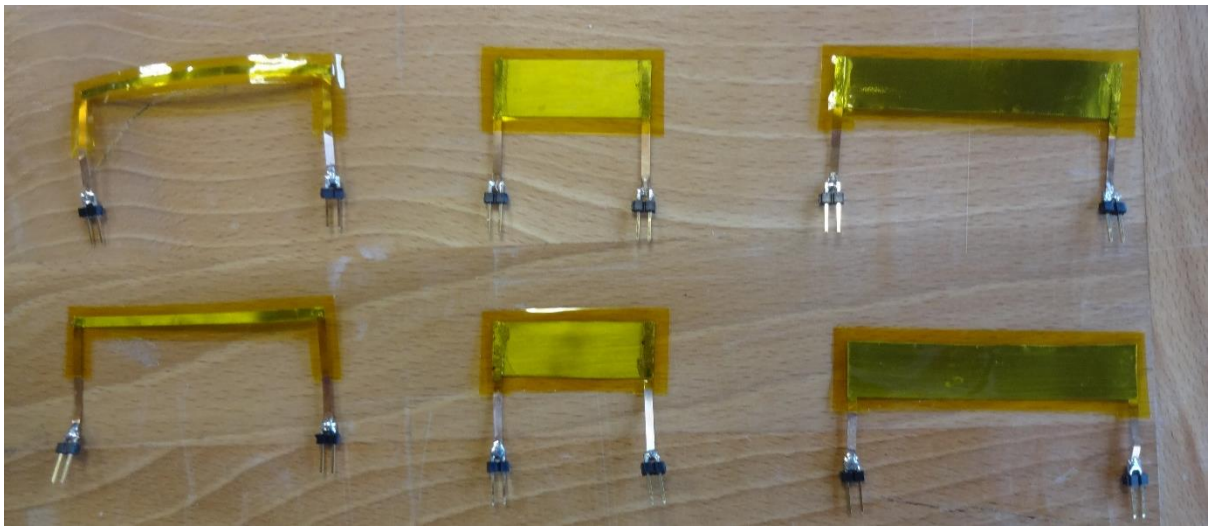
Material:

- Stainless steel 316L 0.1mm thick (CERN store scem 44.59.20.110.8)
- Kapton tape 70µm thick (scem 04.94.70.100.3)
- Copper CuSn6 50µm thick
- Solder SnPb (60/40 scem 29.20.01.304.9) + huile a braser F-SW11 - DIN 8511 (scem 29.30.01.120.8)

Assembly:

3 different designs (size – CF Glyn documents)
Heater design 1: Stainless steel 0.1mm thick * 60mm long * 2mm wide
Heater design 2: Stainless steel 0.1mm thick * 60mm long * 12mm wide
Heater design 3: Stainless steel 0.1mm thick * 35mm long * 12mm wide

2 copper leads (in CuSN6, 1/1.mm wide, 50µm thick) and 2 connectors (Fischer Elektronik SL1.025.36Z, male, 2.54mm, 2 pins) are soldered on each side of the Stainless steel strip. The conectors are used to perform 4 wires measurements and allow the powering of the assembly.
Kapton tapes are added on each side of stainless the steel sheet.



Measures / Results:

HTS Spot Heaters							
16/06/2015			Resistance (mΩ) - 4 wires Keithley 2000				
			1st measure		after 10 cycle liq N2		theoretical
Name	Spot Heaters #	size	@ T=21.5C	@ T=Liq N2	@ T=21.5C	@ T=Liq N2	T=77K
Design 1	1	60*2*0.1	228	168	225	167	158.0
Design 1	2	60*2*0.1	249	183	252	182	158.0
Design 2	1	60*12*0.1	76.6	54.0	70	51	26.3
Design 2	2	60*12*0.1	70.6	52.5	63	48	26.3
Design 3	1	35*12*0.1	59.6	45.6	55	44	15.3
Design 3	2	35*12*0.1	55.5	38.0	58	36	15.3

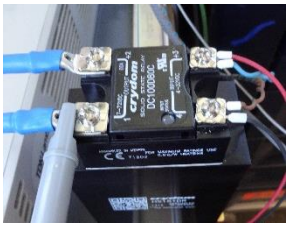
- **<u>High Power signal generator for HTS spot heater</u>**

  <u>Equipment used:</u>
  - Computer
  - Ni software + NI modules (DAQ mx, mathscript RT, …)
  - Compact DAQ chassi NI 9171 USB

  - Compact DAQ card NI 9403

  - Diode T70HFL20s02
    In order to protect Power supply from reverse current

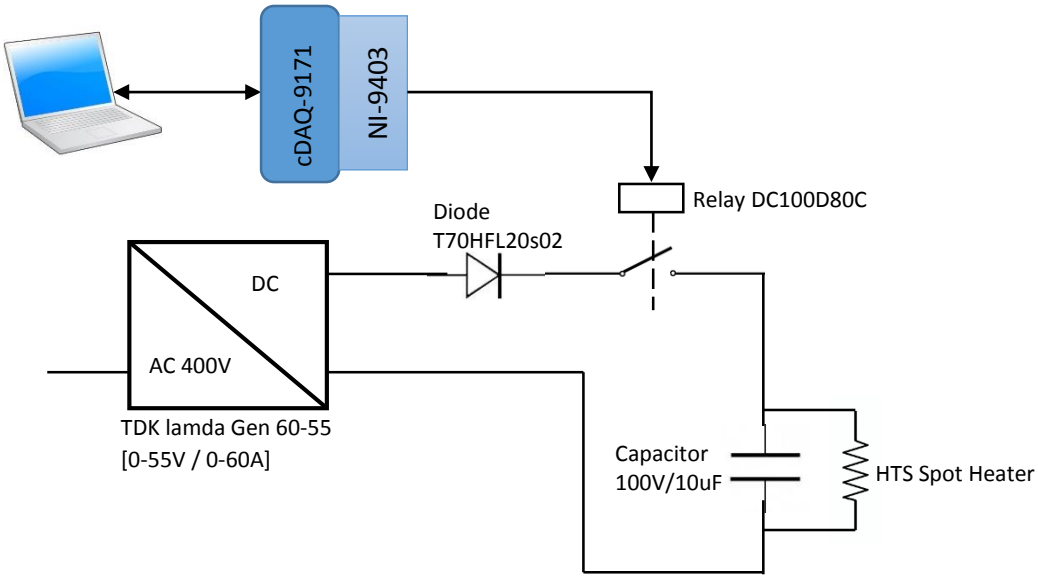
  - Solid state relay Crydom DC100D80C with its cooler



  - DC Power supply TDK Lamda Gen60-55

  - Electrolytic Capacitor Philips 100V 10µF
    To reduce current spike

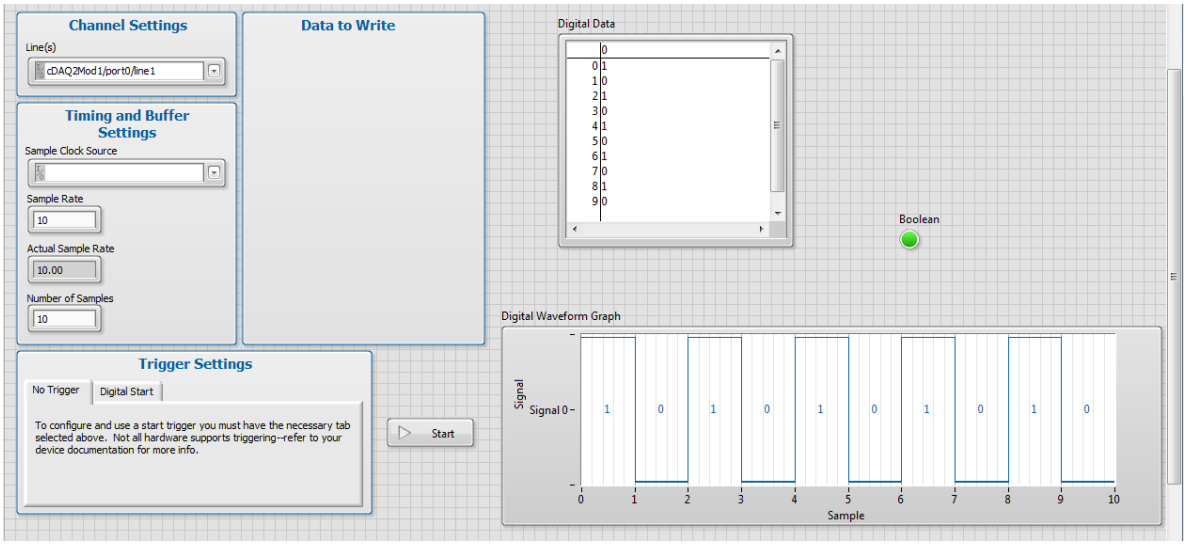
Assembly:



Labview interface:

Name: Square signal generator

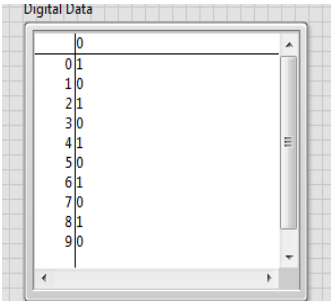
This interface can be used alone or can be integrated in another interface to perform temperature measurements.

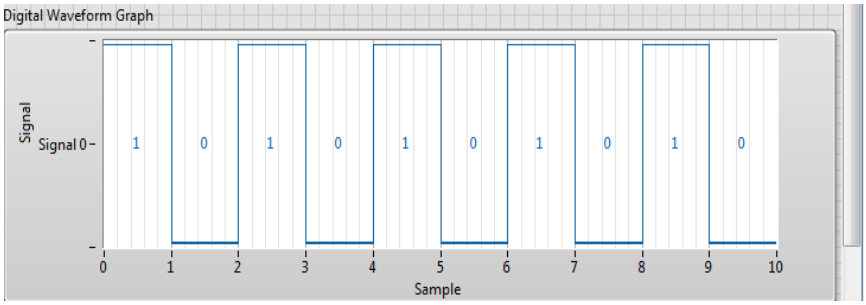


Functions / Results:

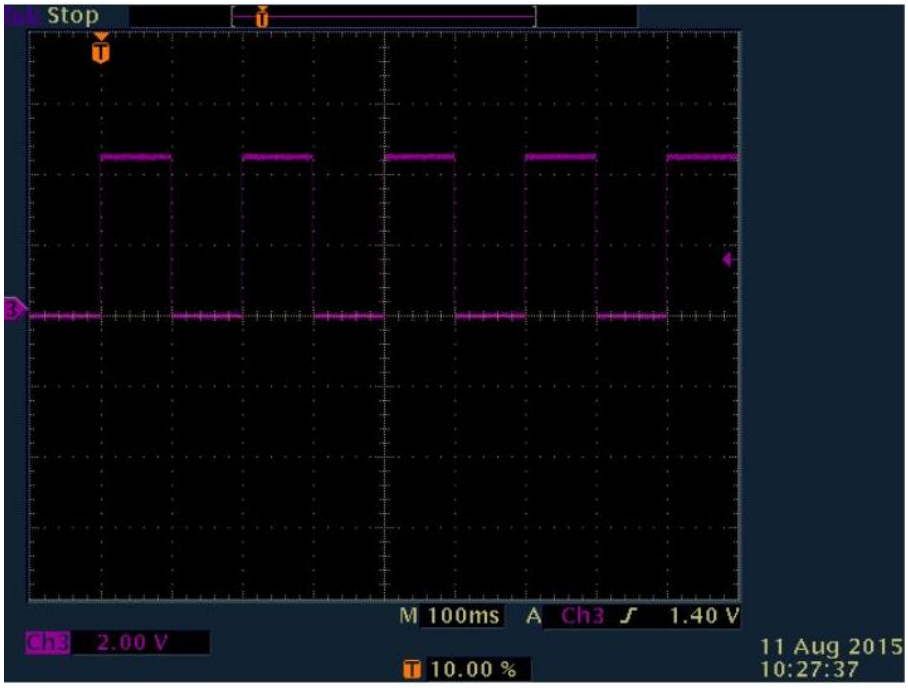
- This system can generate a high power signal between 0 to 55V and 0 to 60A
- It generates a square signal with a maximal duration of 1s (can be modified)
- The square state (high or low) can be programmed with minimum adaptable steps of 100ms (can be modified)

Example of programmed sequence:





Measured results on the SH terminal using an oscilloscope



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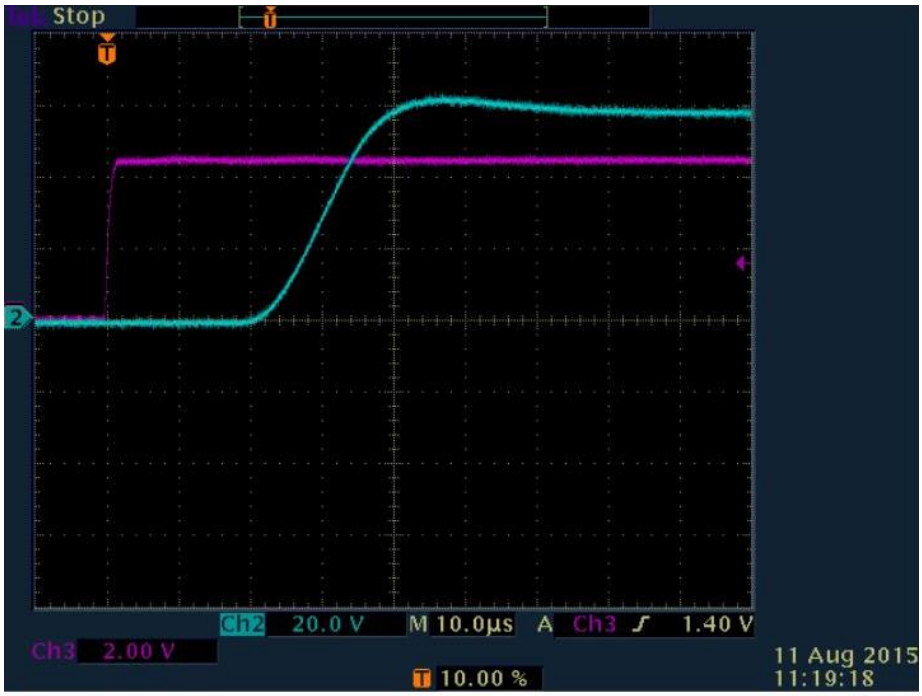
Delay and rising time:

The delay between the digital output signal on the relay and the high power signal on the SH is around 20µs.

The rising edge of the square signal is not perfectly straight. The rising time is about 16µs



Measure done on 2 power 50W resistances in parallel at 10V, 20V, 30V, 40V, 50V and 60V.

For U=60V the current is about I=4A

- **Temperature measurement with different sensor**

Material used:

- Different sensors used to temperature measurement:
  - Thermocouple K stainless steel , 0.5mm diameter (RS No 443-7939)

  - Thermocouple T (RS No 621-2164)

  - PT100, IST INNOVATIVE SENSOR TECHNOLOGY P0K1.202.3FW.A.007 (Farnell No 2191840), size 2mm*2mm

  - PT100, Labfacility DM314 class A (Farnell No 1289670), size 1.2mm*1.6mm

- Data acquisition system Compact CompacDAQ chassi NI cDAQ-9178 USB

- Compact DAQ card NI 9219 (resistance 4 wires), NI 9217 (Pt100), NI 9211 (Thermocouple)

Software used : Read_Record_thermocouple.vi
Read_Record_RTD

Assembly:

All the sensors are on the surface, in the middle of a power resistance 30Ω 50W, in paralelel with another one. A kapton tape is added to ensure a good contact.

Measures / Results:

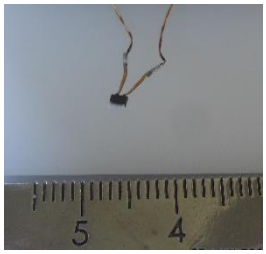
- **Temperature measurement on HTS SpotHeater (Air and N2 liquide)**

Material used:

- 2 sensors used to measure temperature :

  - PT100, IST INNOVATIVE SENSOR TECHNOLOGY P0K1.202.3FW.A.007 (Farnell No 2191840), size 2mm*2mm

  - PT100, Labfacility DM314 class A (Farnell No 1289670), size 1.2mm*1.6mm



- Data acquisition system Compact CompacDAQ chassi NI cDAQ-9178 USB

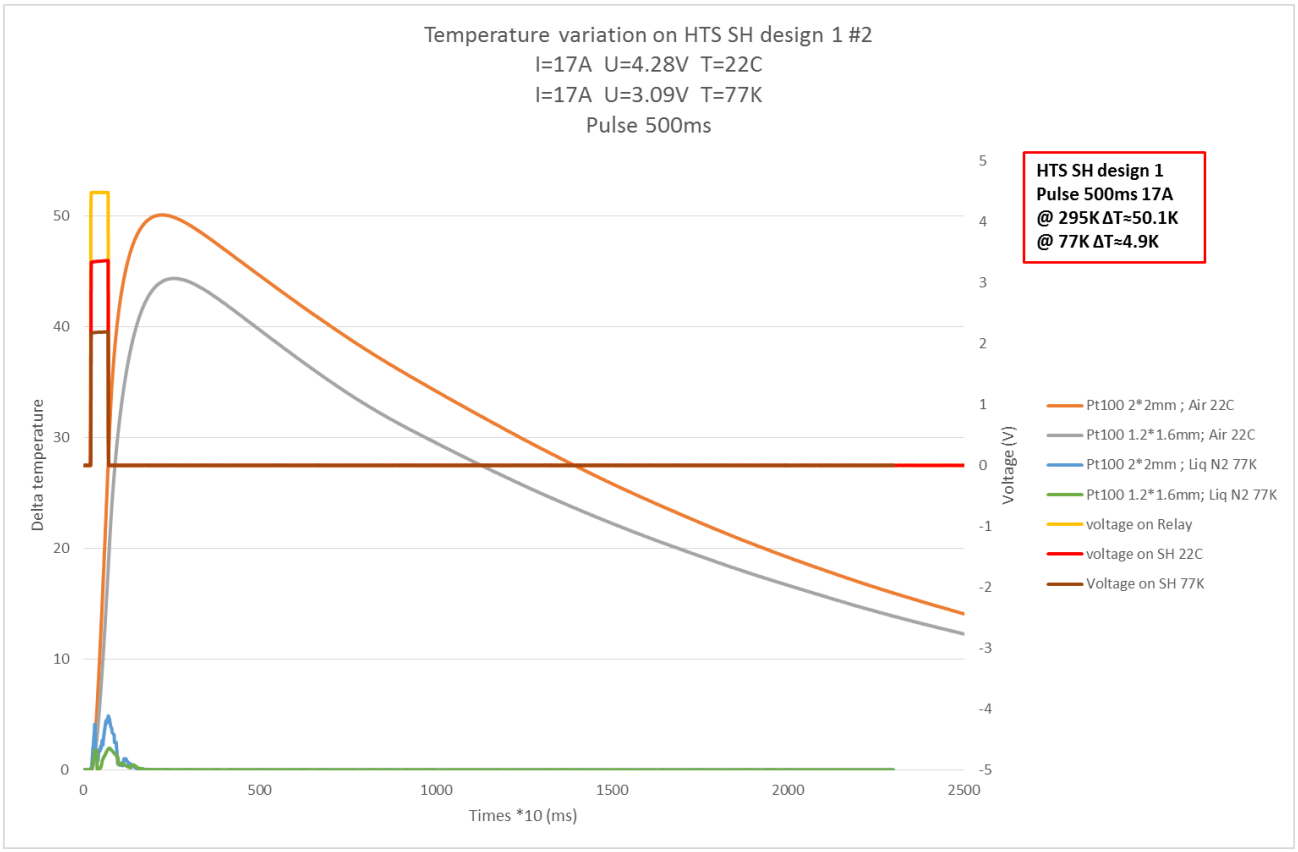
- Compact DAQ card NI 9217 (Pt100)
- Soft Read_Record_RTD
- High power signal generator for HTS

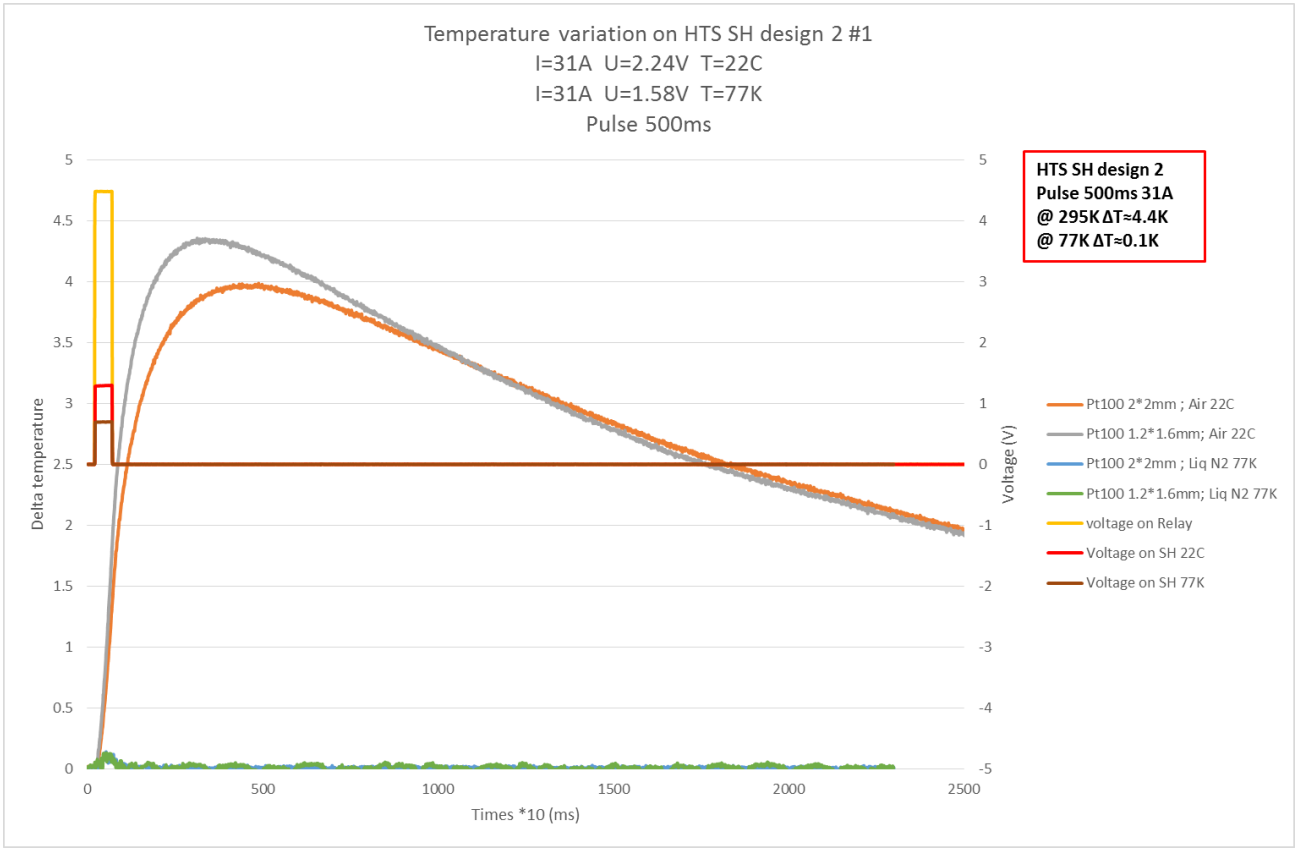
Assembly:

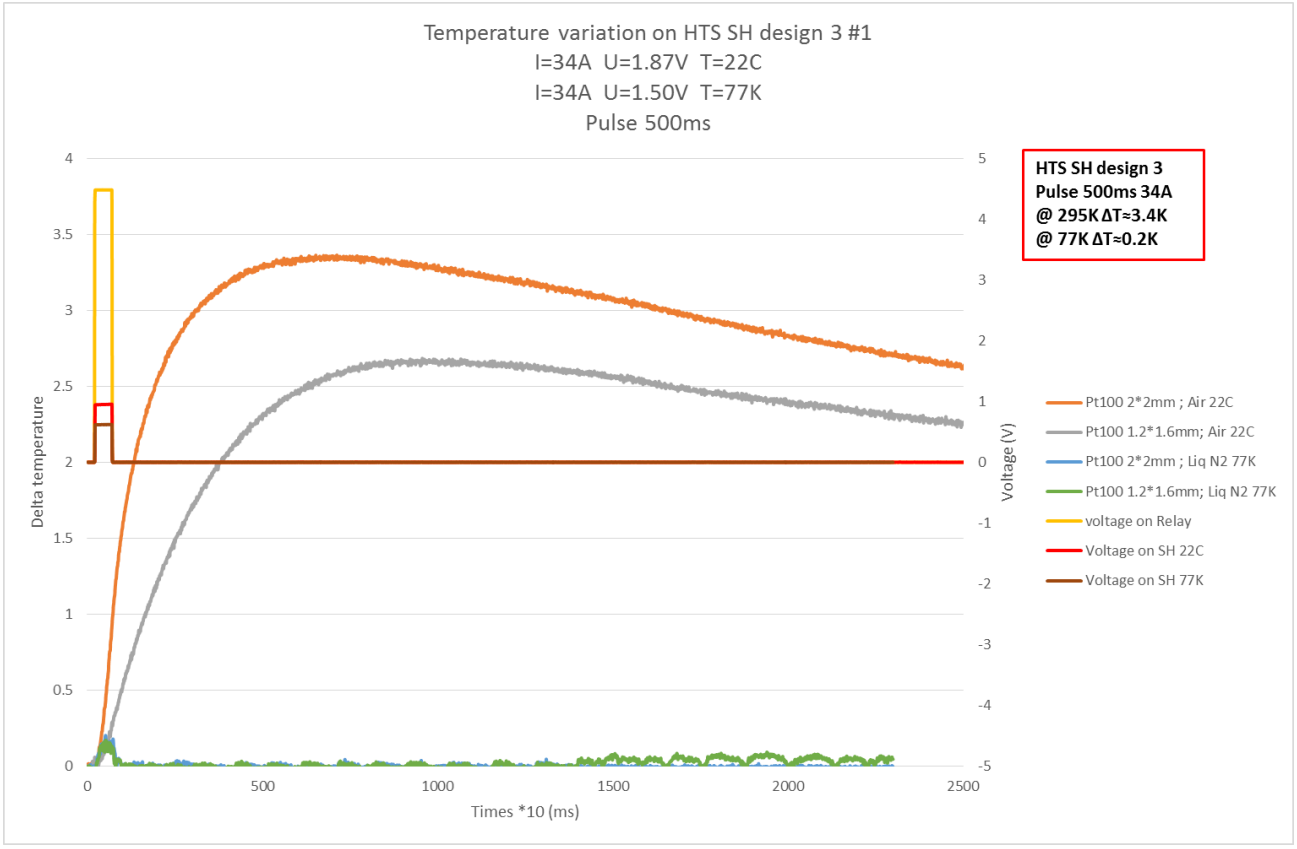
All the sensors are on the surface in the middle of a power resistance 30Ω 50W in parallel with another one. A kapton tape is added to ensure a good contact.

Measures / Results:

The liquid nitrogen temperature is at the limit of Pt100 range.
In liquid nitrogen the temperature response is really different. Maybe some N2 gas affects the thermal exchange between the SH and the sensor.


Temperature variation on HTS SH design 1 #2
I=17A U=4.28V T=22C
I=17A U=3.09V T=77K
Pulse 500ms
HTS SH design 1
Pulse 500ms 17A
@ 295K ΔT≈50.1K
@ 77K ΔT≈4.9K
Delta temperature
Voltage (V)
Times *10 (ms)
Pt100 2*2mm ; Air 22C
Pt100 1.2*1.6mm; Air 22C
Pt100 2*2mm ; Liq N2 77K
Pt100 1.2*1.6mm; Liq N2 77K
voltage on Relay
voltage on SH 22C
Voltage on SH 77K

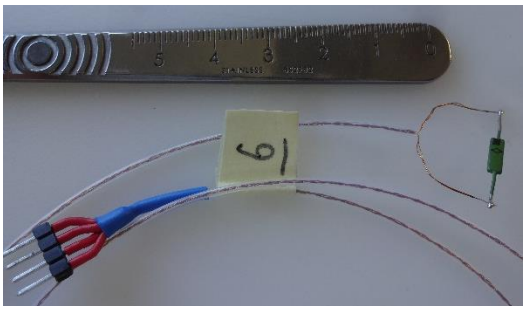

Temperature variation on HTS SH design 2 #1
I=31A U=2.24V T=22C
I=31A U=1.58V T=77K
Pulse 500ms
HTS SH design 2
Pulse 500ms 31A
@ 295K ΔT≈4.4K
@ 77K ΔT≈0.1K
Delta temperature
Voltage (V)
Times *10 (ms)
Pt100 2*2mm ; Air 22C
Pt100 1.2*1.6mm; Air 22C
Pt100 2*2mm ; Liq N2 77K
Pt100 1.2*1.6mm; Liq N2 77K
voltage on Relay
Voltage on SH 22C
Voltage on SH 77K


Temperature variation on HTS SH design 3 #1
I=34A U=1.87V T=22C
I=34A U=1.50V T=77K
Pulse 500ms
HTS SH design 3
Pulse 500ms 34A
@ 295K ΔT≈3.4K
@ 77K ΔT≈0.2K
Delta temperature
Voltage (V)
Times *10 (ms)
Pt100 2*2mm ; Air 22C
Pt100 1.2*1.6mm; Air 22C
Pt100 2*2mm ; Liq N2 77K
Pt100 1.2*1.6mm; Liq N2 77K
voltage on Relay
Voltage on SH 22C
Voltage on SH 77K

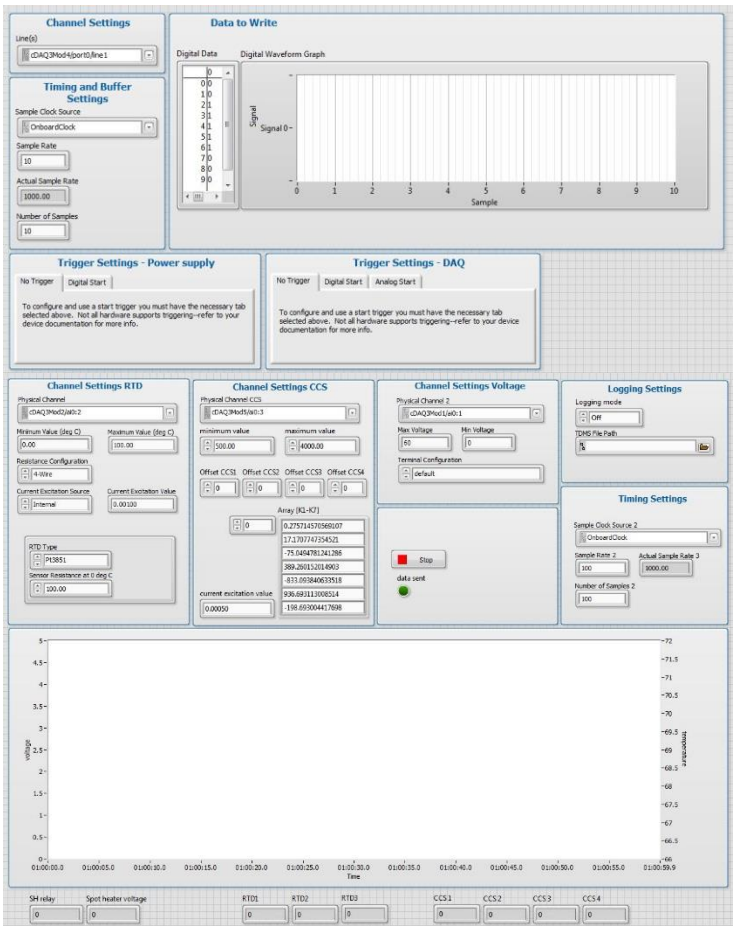
- **<u>Temperature measurement on HTS feather.zero.0</u>**

  <u>Material used:</u>

  - 4 carbon ceramic sensors TMi-CCS

  - 1 HTS Spot heater design 2
  - High power signal generator for HTS
  - Coil HTS feather.zero.0 (one end is cut)
  - Data acquisition system Compact CompacDAQ chassi NI cDAQ-9178 USB
  - Compact DAQ card NI 9219 (resistance 4 wires), NI 9217 (Pt100), NI 9211 (Thermocouple)
  - Software “Main_SpotHeater_CCS_RTD_tempereature_DAQ”
    This labview interface is able to control the high power signal generator and performs temperature acquisition.

  The software measures and records the temperature using 2 Pt100 and 4 CCS sensors. The CCS resistance values are directly converted in temperature using

specific adaptable coefficients and offset. The measurement and the signal generator are started using a common external trigger.

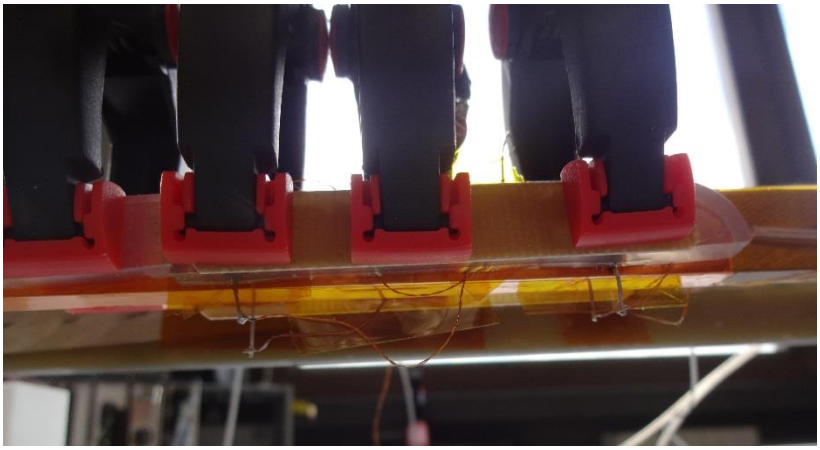
Assembly:

HTS feather0_0 is a coil made off 5 turns on one side using HTS dummy cable.
The SH is directly in contact with the coil on the inner side.opposite to the layer jump.

The SH is hold in place with a kapton tape. Some thermal Apiezon grease is added between the coil and the SH.

CCS are placed on the SH and on the outer side of the coil. The sensor is hold in contact using a kapton tape and thermal grease.

To improve the contact, all the system is tight between small plastic pliers using 2 thick silicon strips

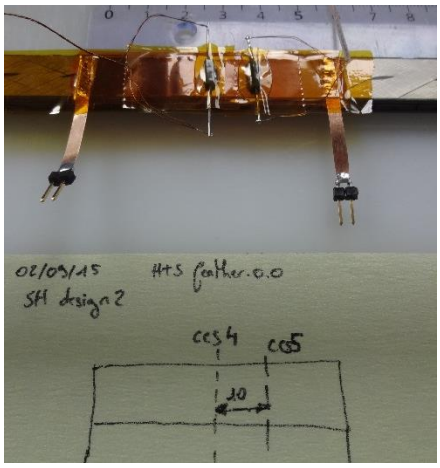


Exact position of the CCS sensor:

The SH in the middle of the coil straight section

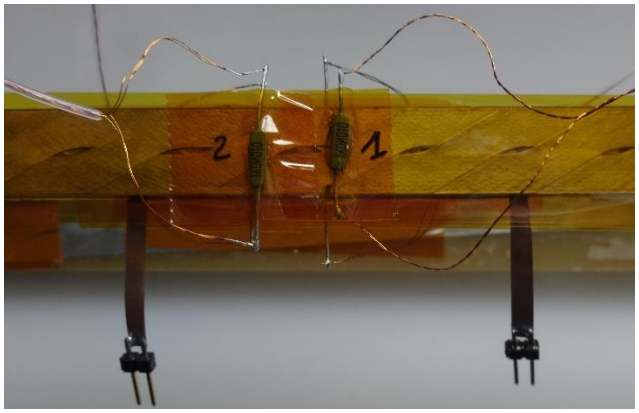
1 CCS is in the middle of the SH design 2 (x= 0mm)

1 CCS is on the SH shifted by 10mm (x= 10mm)



1 CCS on the outer side of the coil and in the middle (x= 0mm)

1 CCS on the outer side of the coil shifted by 10mm (x = 10mm)



The measurement is performed in nitrogen gas. The sensors and the SH are not plunged in the nitrogen. The liquid level is just below the SH. So the temperature of the sensor is a little bit below 100K.

In the isotherm box the coil is not horizontal but tilted. The non-connexion coil side is immersed in LN2.

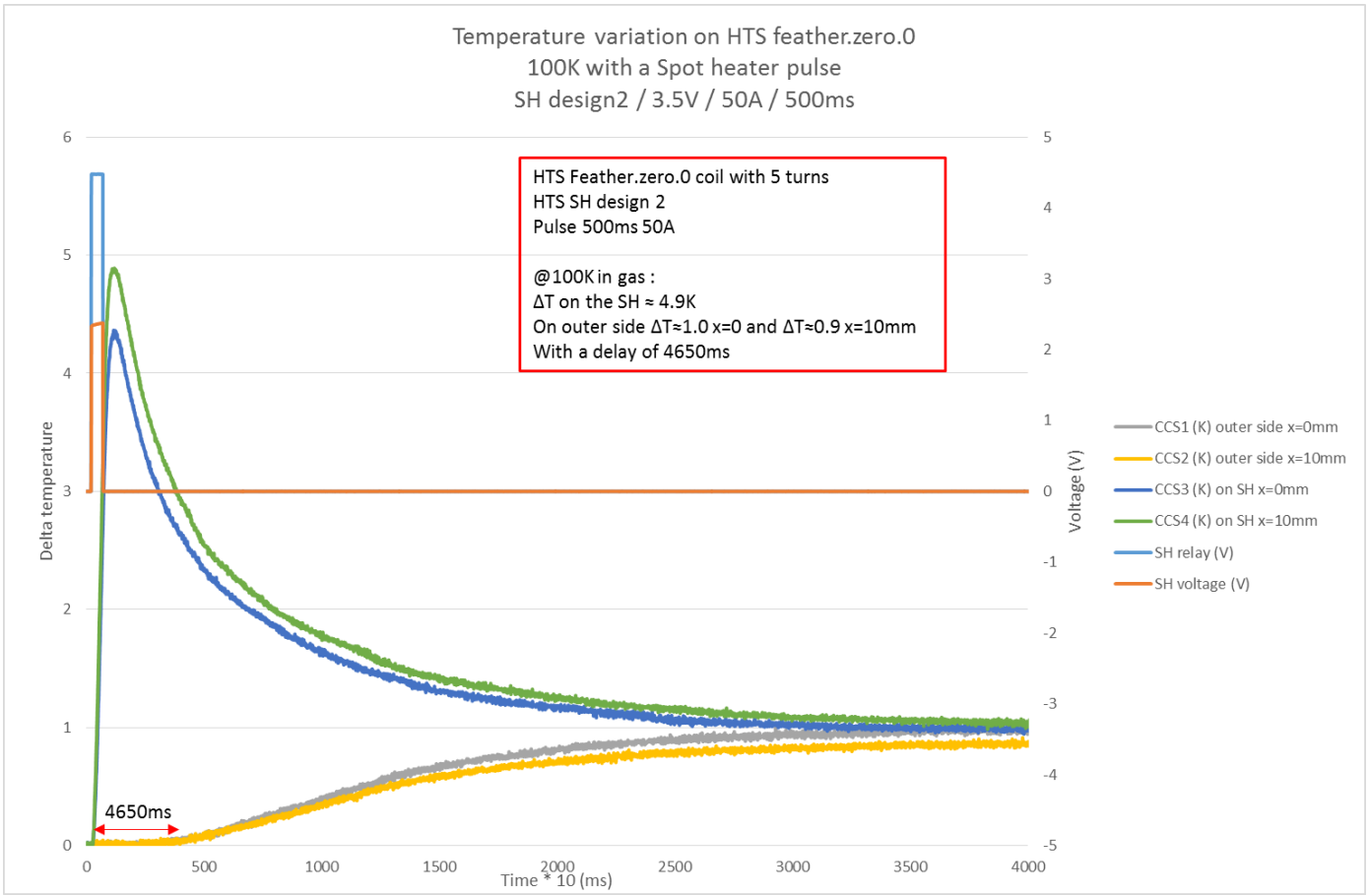
Measures / Results:

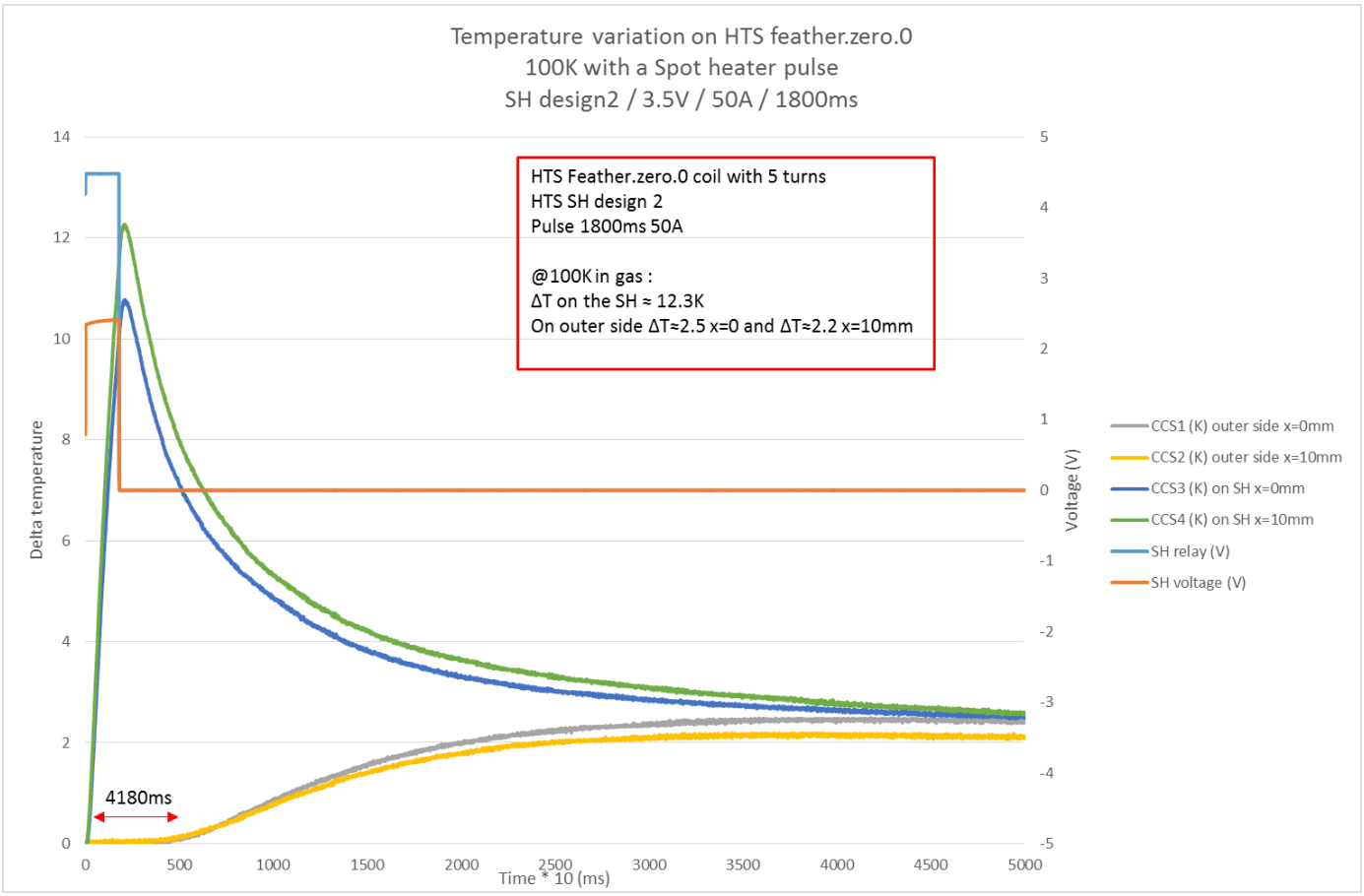
Measurement have been performed using different pulse duration: 500ms, 700ms, 900ms, 1200ms, 1400ms, 1600ms and 1800ms.

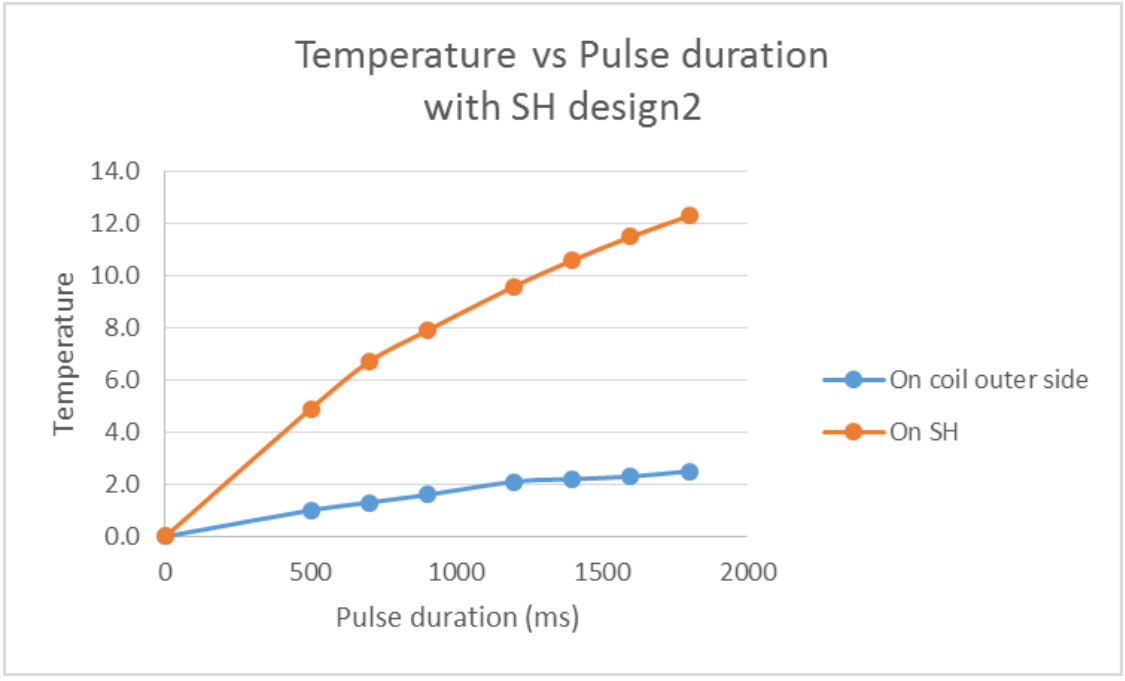
There is a delay about 4.5s between the SH temperature raising and the CCS temperature measurement on the opposite side. The thermal conductivity in the transverse way with only 5 turns is not high-performance (insulation layer, resin,…)

HTS Feather.zero.0																
Temperature measurement																
Pulse SH design2	3.5V 50A 500 ms				3.5V 50A 700 ms				3.5V 50A 900 ms				3.5V 50A 1200 ms			
	Outer coil		On SH		Outer coil		On SH		Outer coil		On SH		Outer coil		On SH	
Sensor position	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm
delta temperature	1.0	0.9	4.4	4.9	1.3	1.1	5.9	6.7	1.6	1.4	7.0	7.9	2.1	1.8	8.5	9.6
delay SH-outer coil	4650ms				4880ms				4290ms				4170ms			

Pulse SH design2	3.5V 50A 1400 ms				3.5V 50A 1600 ms				3.5V 50A 1800 ms			
	Outer coil		On SH		Outer coil		On SH		Outer coil		On SH	
Sensor position	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm	x=0mm	x=10mm
delta temperature	2.2	1.8	9.4	10.6	2.3	2.0	10.1	11.5	2.5	2.2	10.8	12.3
delay SH-outer coil	4630ms				4550ms				4180ms			




Temperature variation on HTS feather.zero.0
100K with a Spot heater pulse
SH design2 / 3.5V / 50A / 1800ms
HTS Feather.zero.0 coil with 5 turns
HTS SH design 2
Pulse 1800ms 50A
@100K in gas :
ΔT on the SH ≈ 12.3K
On outer side ΔT≈2.5 x=0 and ΔT≈2.2 x=10mm
Delta temperature
Voltage (V)
Time * 10 (ms)
4180ms
CCS1 (K) outer side x=0mm
CCS2 (K) outer side x=10mm
CCS3 (K) on SH x=0mm
CCS4 (K) on SH x=10mm
SH relay (V)
SH voltage (V)


Temperature vs Pulse duration
with SH design2
Temperature
Pulse duration (ms)
On coil outer side
On SH

- **Temperature measurement on HTS feather.zero.0 with copper tape wrapping**

Material used:

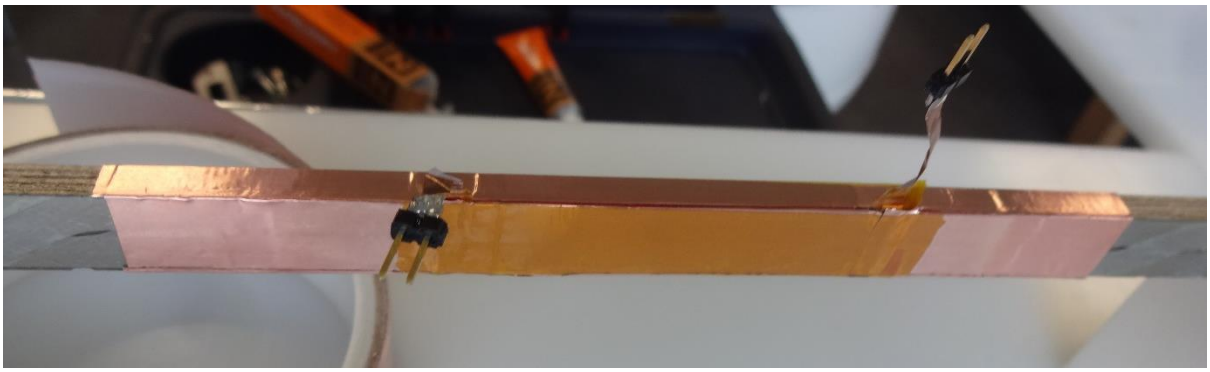
- 4 carbon ceramic sensors TMi-CCS
- 1 HTS Spot heater design 2
- High power signal generator for HTS
- Coil HTS feather.zero.0 (one end is cut)
- Data acquisition system Compact CompacDAQ chassi NI cDAQ-9178 USB
- Compact DAQ card NI 9219 (resistance 4 wires), NI 9217 (Pt100), NI 9211 (Thermocouple)
- Software “Main_SpotHeater_CCS_RTD_tempereature_DAQ”
- Copper tape

Assembly:

The SH is directly in contact with the coil on the inner side opposite to the layer jump.

The SH is hold in place with a kapton tape. Some thermal grease Apiezon is added between the coil and the SH.

A copper tape surrounds the coil and the SH.



On each side, a layer of kapton tape is added to insulate CCS sensor from the copper.

CCS hold in contact with kapton tape and thermal grease, plastic pliers and silicone strips as the previous assembly.

Exact position of the CCS sensor:

The SH in the middle of the coil straight section.

1 CCS is in the middle of the SH design 2 (x= 0mm)

1 CCS is on the SH shifted by 10mm (x= 50mm)

1 CCS on the outer side of the coil and in the middle (x= 0mm)

1 CCS on the outer side of the coil and shifted by 50mm (x = 50mm)

The measurement is performed in N2 gas as the previous assembly. This time the temperature is about 90K.

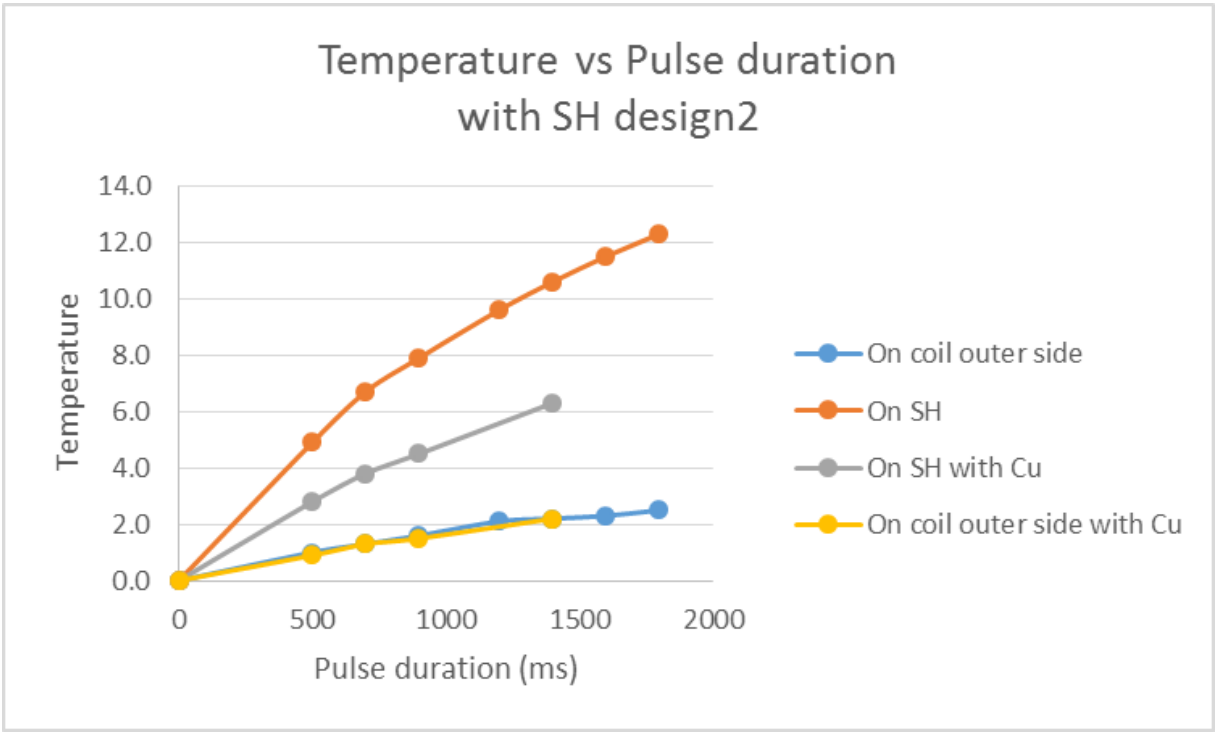
Measures / Results:

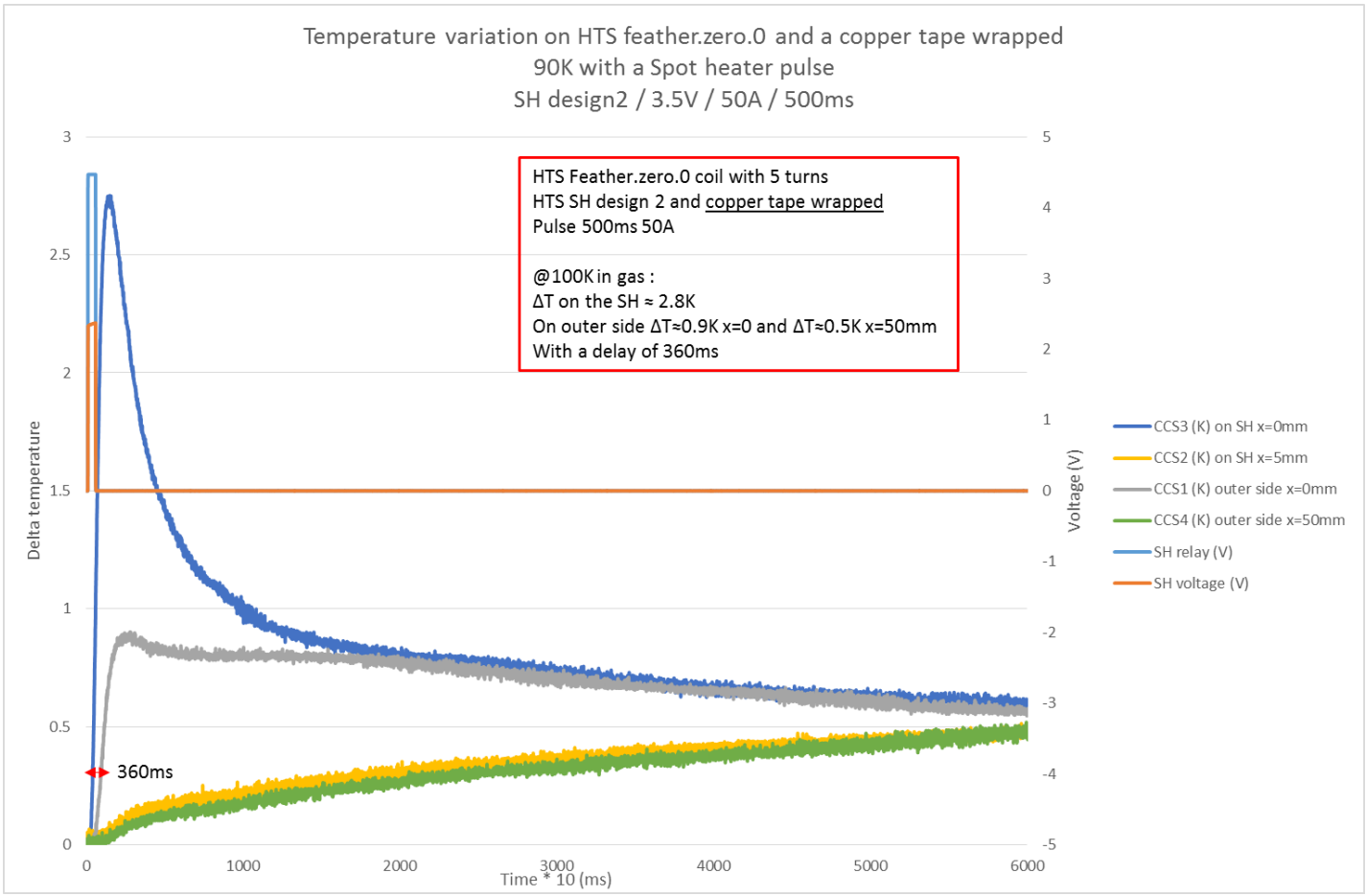
Measurements have been performed using different pulse duration: 500ms, 700ms, 900ms, 1400ms and 1800ms

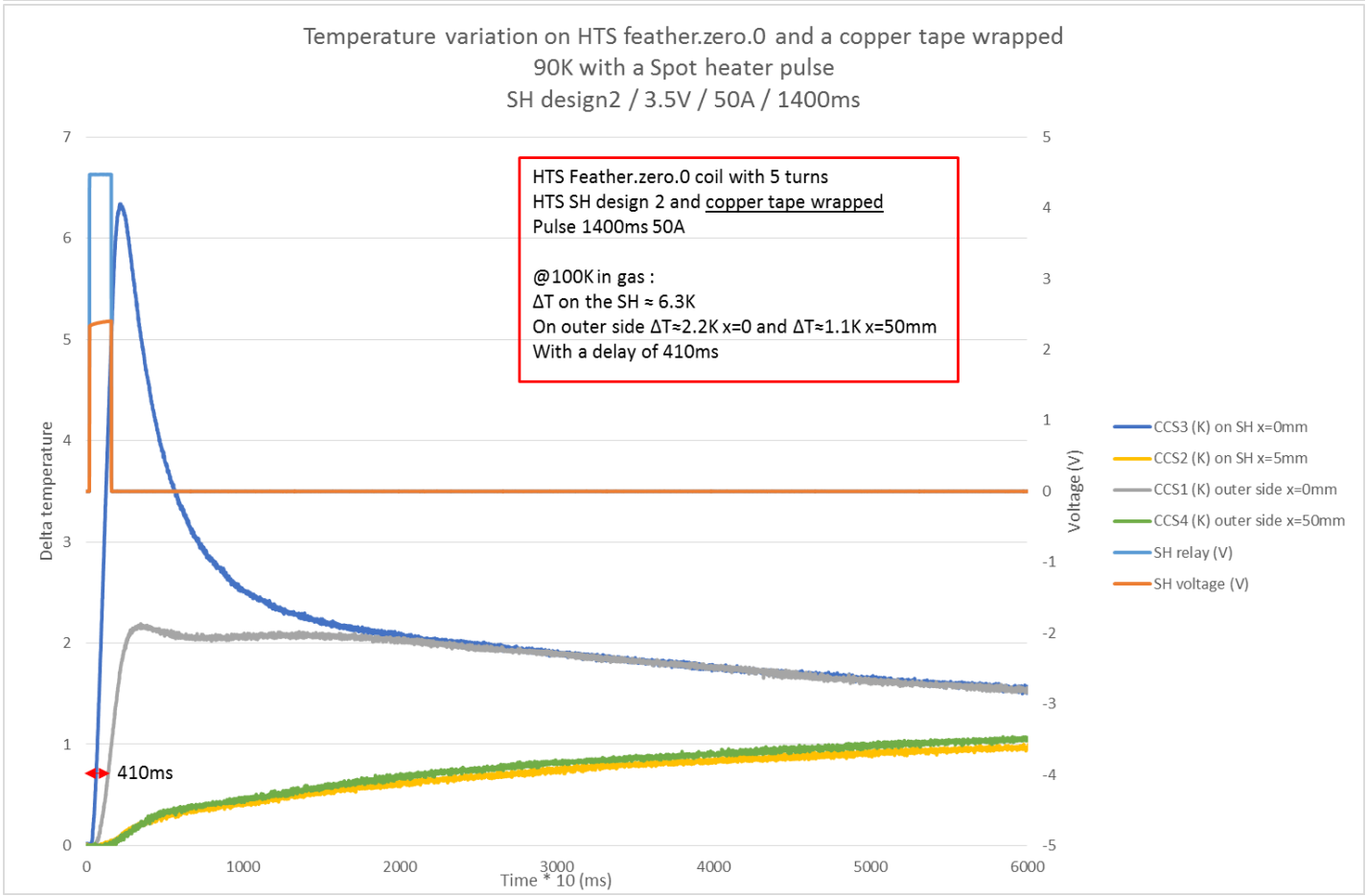
HTS Feather.zero.0 with copper tape wrapped around																
Temperature measurement																
Pulse SH design2	3.5V 50A 500 ms				3.5V 50A 700 ms				3.5V 50A 900 ms				3.5V 50A 1400 ms			
	Outer coil		On SH		Outer coil		On SH		Outer coil		On SH		Outer coil		On SH	
Sensor position	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm	x=0mm	x=50mm
delta temperature	0.9	0.5	2.8	0.5	1.3	0.9	3.8	0.9	1.5	0.9	4.5	0.8	2.2	1.1	6.3	1.0
delay SH-outer coil	360ms				260ms				390ms				410ms			

The delay between SH temperature rising and the CCS response on the opposite side is reduce. The delay is about 400ms.
The copper tape wrapped around the coil strongly increase the transverse thermal conductivity.

In the longitudinal coil section, the copper tape reduce the delay too but the signal amplitude is lower.
To keep a high signal range the shift between sensors must be reduced.




Temperature variation on HTS feather.zero.0 and a copper tape wrapped
90K with a Spot heater pulse
SH design2 / 3.5V / 50A / 500ms
HTS Feather.zero.0 coil with 5 turns
HTS SH design 2 and copper tape wrapped
Pulse 500ms 50A
@100K in gas :
ΔT on the SH ≈ 2.8K
On outer side ΔT≈0.9K x=0 and ΔT≈0.5K x=50mm
With a delay of 360ms
360ms
Delta temperature
Voltage (V)
Time * 10 (ms)
CCS3 (K) on SH x=0mm
CCS2 (K) on SH x=5mm
CCS1 (K) outer side x=0mm
CCS4 (K) outer side x=50mm
SH relay (V)
SH voltage (V)


Temperature variation on HTS feather.zero.0 and a copper tape wrapped
90K with a Spot heater pulse
SH design2 / 3.5V / 50A / 1400ms
HTS Feather.zero.0 coil with 5 turns
HTS SH design 2 and copper tape wrapped
Pulse 1400ms 50A
@100K in gas :
ΔT on the SH ≈ 6.3K
On outer side ΔT≈2.2K x=0 and ΔT≈1.1K x=50mm
With a delay of 410ms
410ms
Delta temperature
Voltage (V)
Time * 10 (ms)
CCS3 (K) on SH x=0mm
CCS2 (K) on SH x=5mm
CCS1 (K) outer side x=0mm
CCS4 (K) outer side x=50mm
SH relay (V)
SH voltage (V)