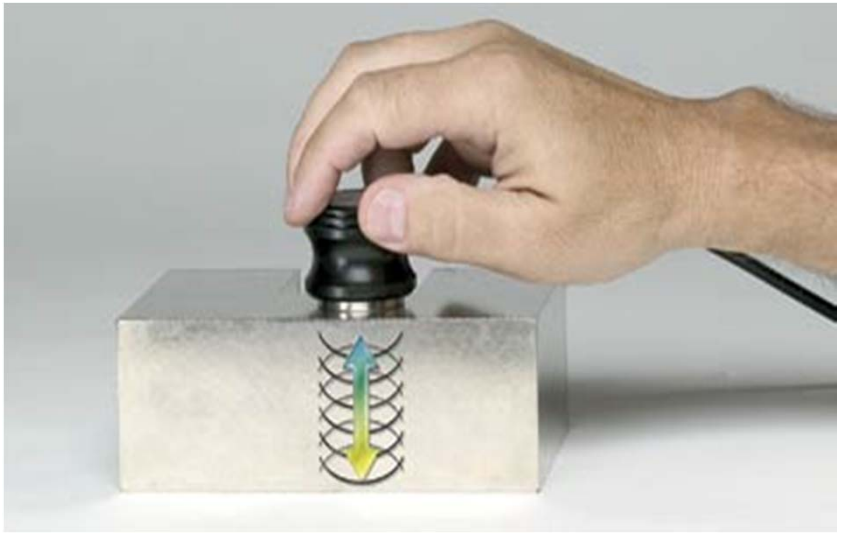
“In-situ” measurement of material removal during BCP

Mircea Stirbet and Peter Kneisel

Principle of ultrasonic thickness measurement



$T = (V) \times (t/2)$

where

T = the thickness of the part

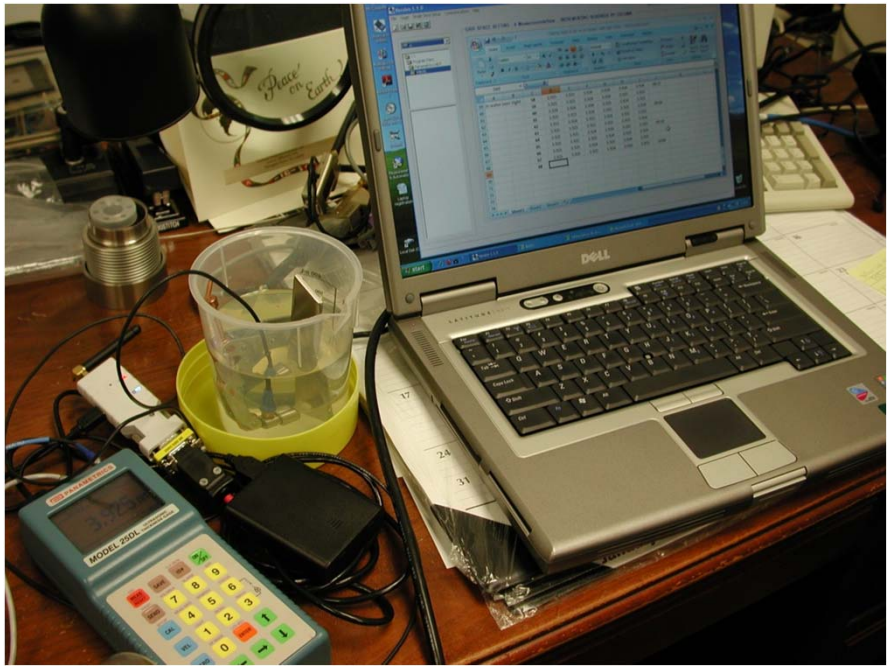
V = the velocity of sound in the test material

t = the measured round-trip transit time

The transducer contains a piezoelectric element which is excited by a short electrical impulse to generate a burst of ultrasonic waves. The sound waves are coupled into the test material and travels through it until they encounter a back wall or other boundary. The reflections then travel back to the transducer, which converts the sound energy back into electrical energy. In essence, the gage listens for the echo from the opposite side. Typically this time interval is only a few millionths of a second. The gage is programmed with the speed of sound in the test material, from which it can then calculate thickness using the simple mathematical relationship

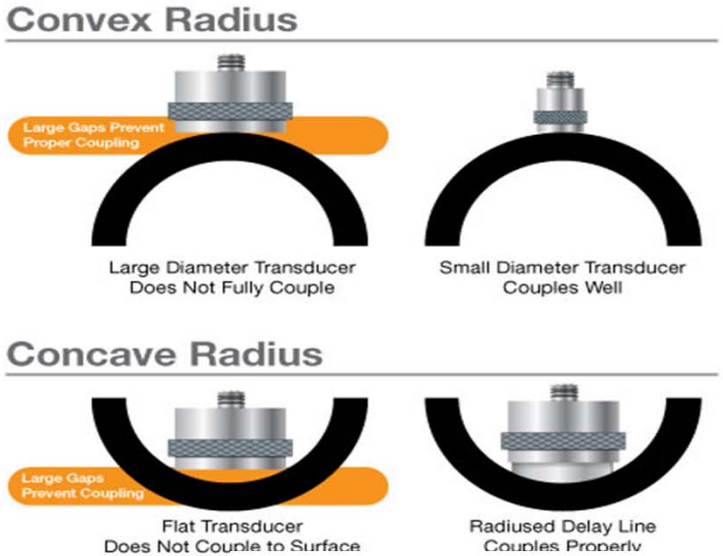
Hardware at JLAB for US measurements

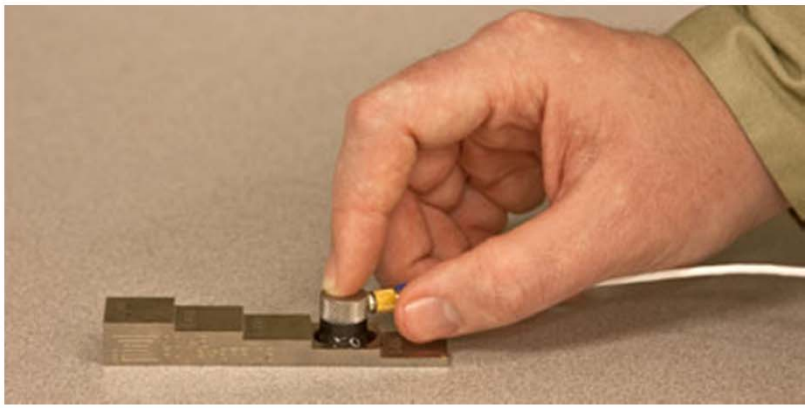
- Panametrics 25DL (old instrument: ~2000)
- Panametrics 25DL Plus (quite new but no more in production)
-Temperature measurement instrumentation
- Laptop and software for data acquisition (via serial port)
- **Wireless replacement** for the serial cable (data can be transmitted over 200 ft.)
- Dealing with measurement errors in ultrasonic thickness measurements…

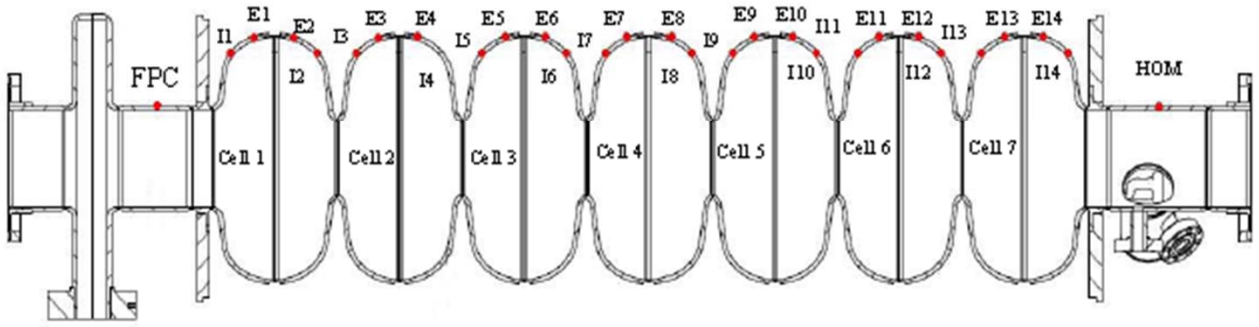


Errors related with:
- US gauge dimensions
- Surface shape
- Surface finish
- Nb fine or large grains
- Instrumental errors
- Operator training

Typical NB thickness measurements done at JLAB

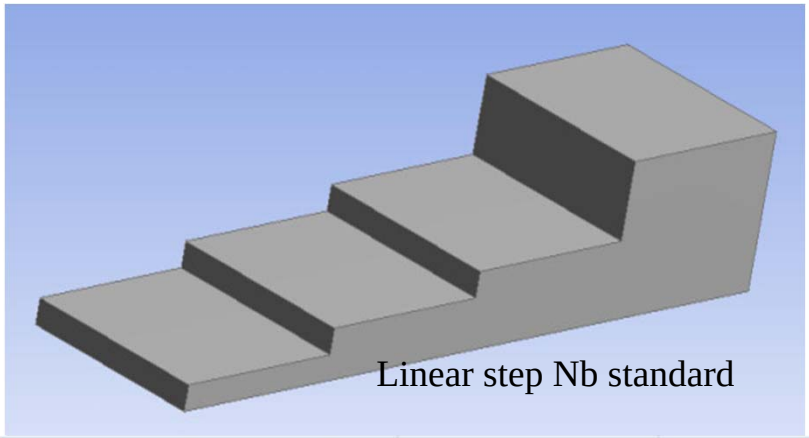




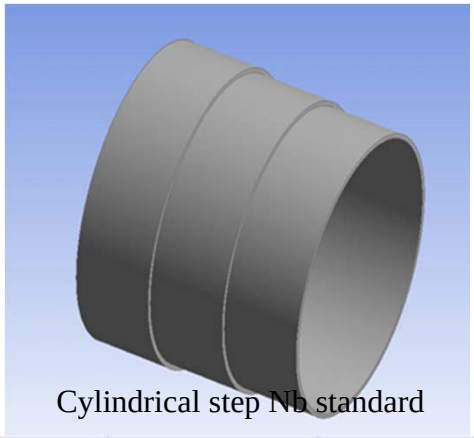


C100 cavity specifying the ultrasonic measurement positions.
Initial cavity wall thickness for beam pipes and cell walls 0.125" (3.2mm).

Nb step standard for Ultrasonic gauge calibration



Linear step Nb standard



Cylindrical step Nb standard

Linear step Nb standard					
	Meas. 1st (mm)	Meas. 2nd (mm)	Meas. 3rd(mm)	Average (mm)	STDEV (mm)
Location of point PNT1A	17.9858	17.9832	17.9848	17.9846	0.001311488
Location of point PNT2A	8.9933	8.9943	8.9917	8.9931	0.001311488
Location of point PNT3A	5.9966	5.9948	5.9943	5.9952	0.001209683
Location of point PNT4A	2.9963	2.9982	2.9961	2.9969	0.001159023
Distance from PNT5A to PNT6A	24.7496	24.7505	24.7492	24.7498	0.000665833

Cylindrical step Nb standard					
	Meas. 1st (mm)	Meas. 2nd (mm)	Meas. 3rd(mm)	Average (mm)	STDEV (mm)
Location of point PNT1 to PNT6	2.6286	2.6258	2.6276	2.6273	0.001158543
Location of point PNT2 to PNT5	2.0940	2.0918	2.0941	2.0933	0.001061446
Location of point PNT3 to PNT4	1.5855	1.5870	1.5877	1.5867	0.000917727

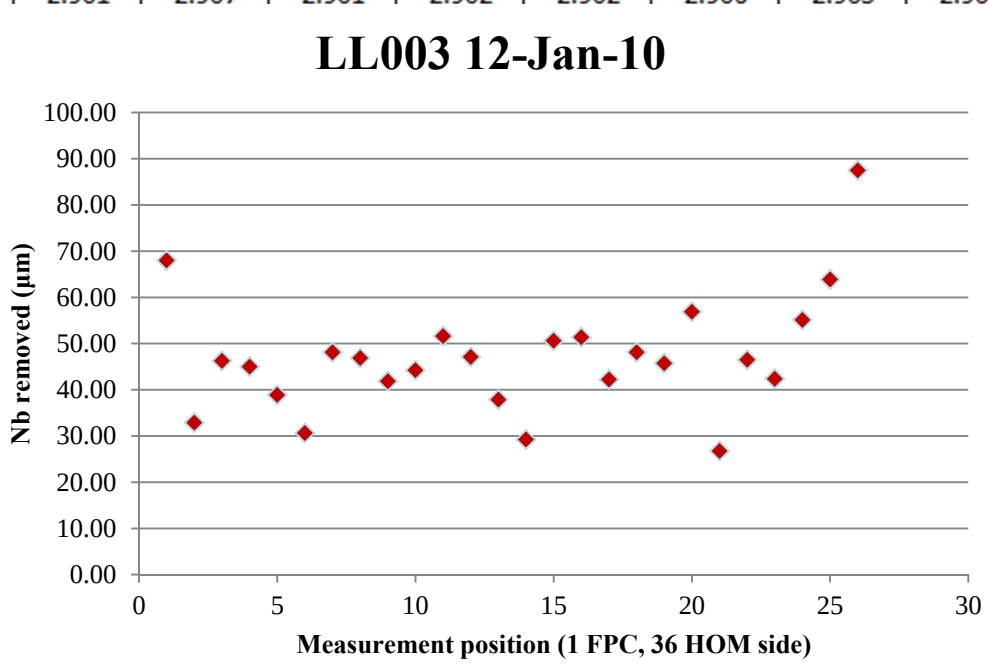
Typical Nb thickness measurements done at JLAB cont

LL003		1st	2nd	3rd	4th	5th	6th	7th	8th	AVG	STDEV	µm Removed
10-Dec-09										(mm)		
FPC	1	2.992	2.992	2.990	2.989	2.961	2.984	2.989	2.999	2.987	0.0113137	N/A
E2	2	3.063	3.065	3.064	3.064	3.046	3.057	3.067	3.048	3.059	0.0081020	N/A
I2	3	2.882	2.881	2.881	2.897	2.891	2.877	2.886	2.890	2.886	0.0066319	N/A
I3	4	2.943	2.954	2.952	2.948	2.948	2.946	2.948	2.948	2.948	0.0033780	N/A
E3	5	3.112	3.108	3.111	3.112	3.115	3.114	3.116	3.120	3.114	0.0036253	N/A
E4	6	3.102	2.938	3.107	3.103	3.097	3.102	3.152	3.095	3.087	0.0629013	N/A
I4	7	2.896	2.905	2.897	2.903	2.890	2.892	2.890	2.892	2.896	0.0057802	N/A
I5	8	2.934	2.928	2.931	2.927	2.942	2.947	2.943	2.939	2.936	0.0074438	N/A
E5	9	3.086	3.081	3.081	3.085	3.083	3.085	3.084	3.087	3.084	0.0022039	N/A
E6	10	3.095	3.095	3.097	3.092	3.099	3.094	3.099	3.084	3.094	0.0048385	N/A
I6	11	2.921	2.923	2.912	2.912	2.936	2.980	2.924	2.923	2.929	0.0220028	N/A
I7	12	2.994	2.992	2.990	2.993	2.992	2.991	2.991	2.988	2.991	0.0018468	N/A
E7	13	3.132	3.125	3.127	3.124	3.129	3.126	3.122	3.120	3.126	0.0038149	N/A
E8	14	3.127	3.127	3.133	3.134	3.141	3.136	3.142	3.133	3.134	0.0055662	N/A
I8	15	2.930	2.937	2.925	2.930	2.924	2.920	2.942	2.939	2.931	0.0078274	N/A
I9	16	2.965	2.968	2.966	2.961	2.964	2.970	2.973	2.964	2.966	0.0038149	N/A
E9	17	3.109	3.109	3.108	3.118	3.111	3.111	3.114	3.110	3.111	0.0032842	N/A
E10	18	3.116	3.110	3.114	3.117	3.117	3.115	3.112	3.114	3.114	0.0024458	N/A
I10	19	2.969	2.965	2.957	2.968	2.971	2.974	2.944	2.936	2.961	0.0137633	N/A
I11	20	2.871	2.879	2.882	2.881	2.880	2.882	2.880	2.878	2.879	0.0035632	N/A
E11	21	2.986	3.008	3.005	2.998	3.017	3.011	3.010	3.006	3.005	0.0094482	N/A
E12	22	3.133	3.137	3.143	3.140	3.140	3.157	3.157	3.145	3.144	0.0087994	N/A
I12	23	2.927	2.940	2.946	2.944	2.920	2.934	2.933	2.905	2.931	0.0136323	N/A
I13	24	2.993	3.000	2.996	2.994	2.997	2.991	2.994	2.994	2.995	0.0027484	N/A
E13	25	3.193	3.174	3.188	3.176	3.180	3.176	3.173	3.185	3.181	0.0072887	N/A
HOM	26	3.117	3.119	3.120	3.124	3.125	3.118	3.120	3.123	3.121	0.0029155	N/A

Typical Nb thickness measurements done at JLAB cont

12-Jan-10										(mm)		(µm)
FPC	1	2.921	2.918	2.917	2.922	2.919	2.918	2.920	2.917	2.919	0.0018516	68.00
E2	2	3.026	3.025	3.024	3.028	3.026	3.029	3.026	3.027	3.026	0.0015980	32.87
I2	3	2.843	2.840	2.841	2.839	2.840	2.838	2.839	2.835	2.839	0.0023261	46.25
I3	4	2.903	2.901	2.907	2.901	2.902	2.902	2.906	2.905	2.903	0.0023261	45.00
E3	5	3.07									0.0031595	38.88
E4	6	3.05									0.0022638	30.62
I4	7	2.84									0.0017728	48.12
I5	8	2.88									0.0016036	46.88
E5	9	3.04									0.0034821	41.88
E6	10	3.05									0.0024749	44.25
I6	11	2.87									0.0027124	51.63
I7	12	2.94									0.0023146	47.13
E7	13	3.09									0.0024928	37.88
E8	14	3.10									0.0025319	29.25
I8	15	2.87									0.0026592	50.62
I9	16	2.91									0.0021381	51.38
E9	17	3.07									0.0028785	42.25
E10	18	3.07									0.0039188	48.13
I10	19	2.91									0.0022520	45.75
I11	20	2.82									0.0012817	56.87
E11	21	2.97									0.0021998	26.75
E12	22	3.100	3.099	3.098	3.094	3.093	3.101	3.099	3.096	3.098	0.0028785	46.50
I12	23	2.892	2.885	2.888	2.891	2.887	2.889	2.888	2.890	2.889	0.0022520	42.38
I13	24	2.941	2.937	2.940	2.940	2.941	2.938	2.942	2.939	2.940	0.0016690	55.13
E13	25	3.113	3.117	3.116	3.119	3.120	3.118	3.118	3.113	3.117	0.0026049	63.87
HOM	26	3.035	3.034	3.031	3.033	3.036	3.034	3.032	3.031	3.033	0.0018323	87.50
										AVG µm Removal		47.14

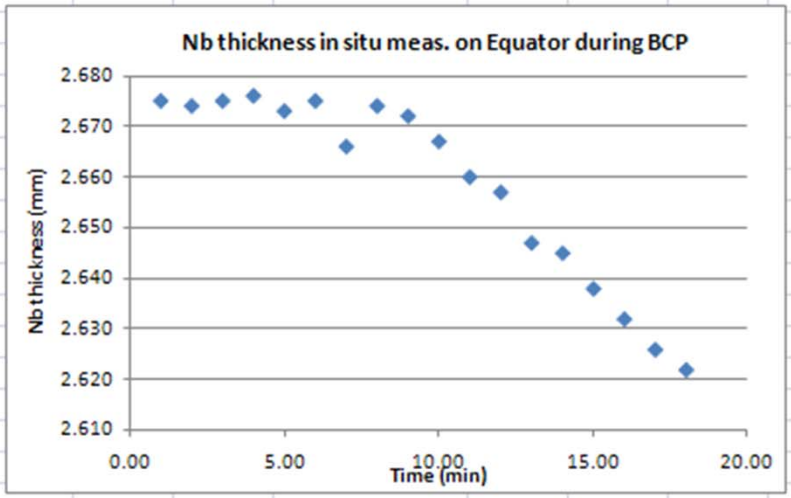
Nb removed = 2.9872 - 2.9473=0.0399mm = 40µm

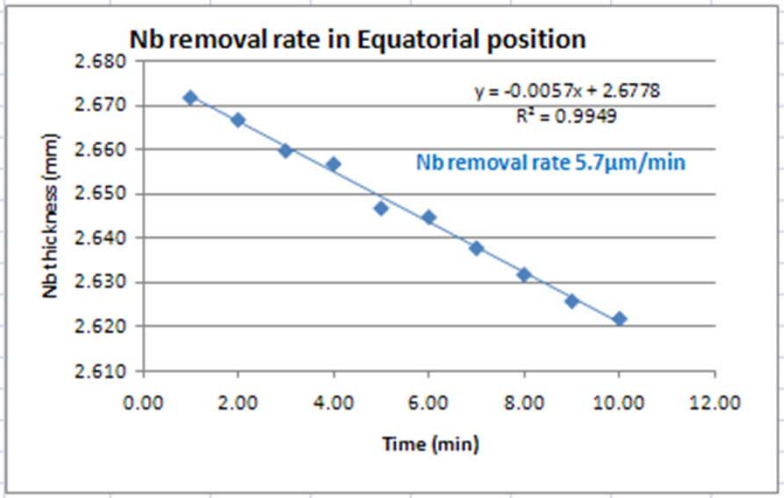


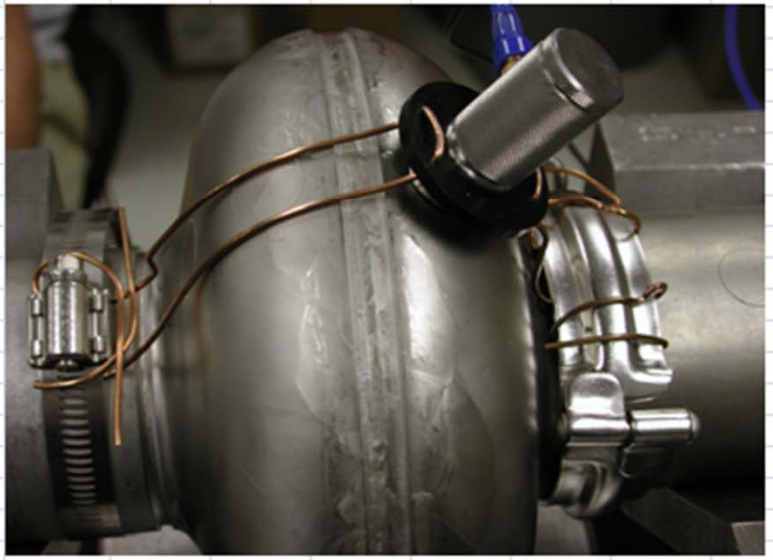
Setup and data acquisition for in situ US measurements

Panametrics Model 25DL
Gauge calibrated against Nb standard
Couplant : glycerin
Initial measurements done on large grains single cell cavity (measurements affected by crystal boundaries) then test done on fine grain 1500 MHz singe cell cavity.

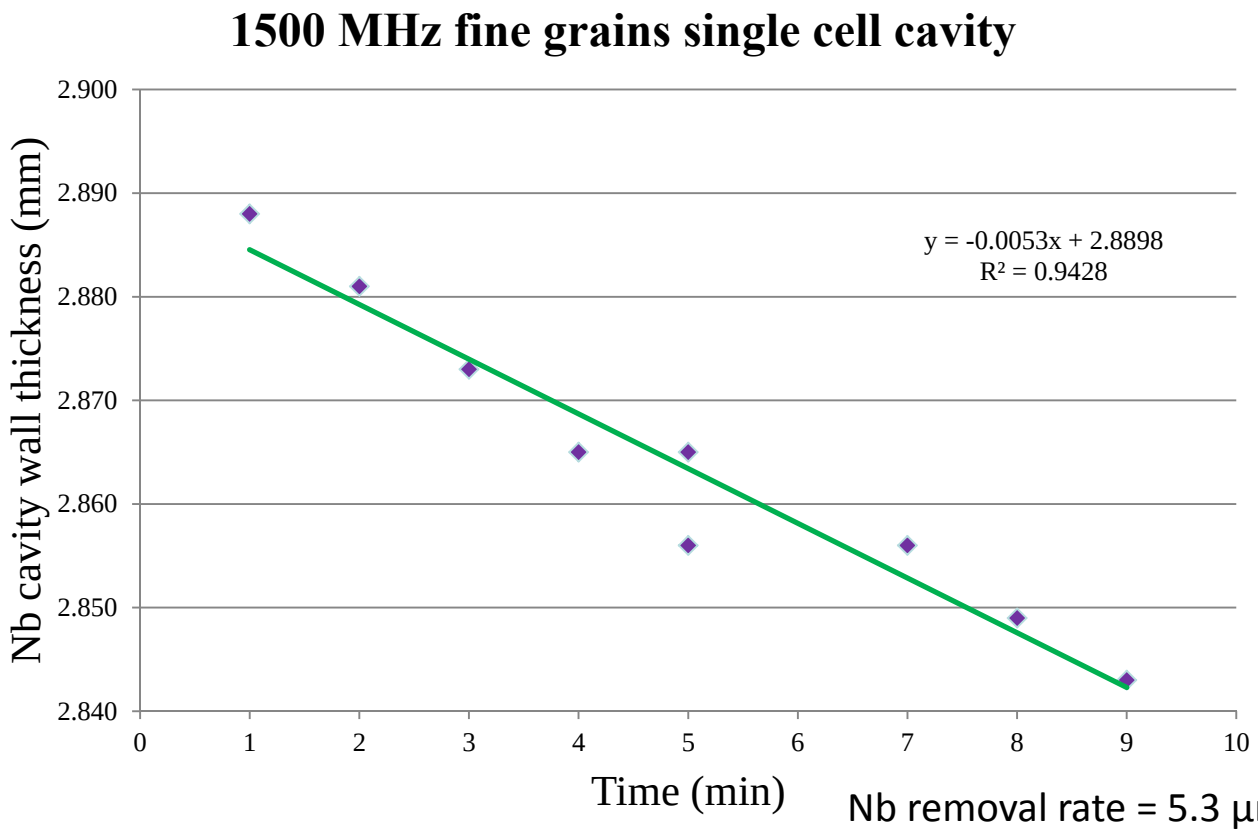
Results large grains cavity (Feb 2010)







Results fine grains cavity (June 2010) cont

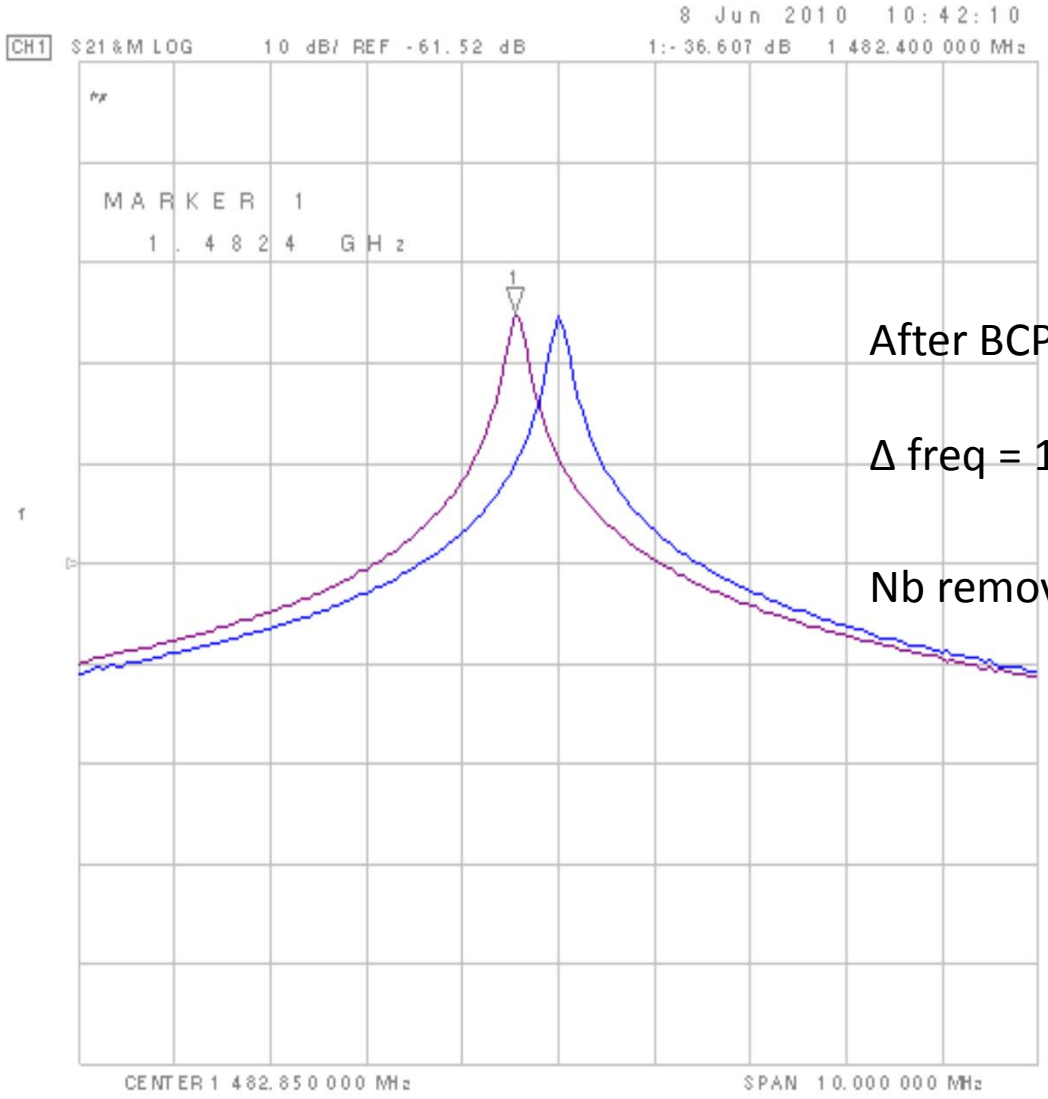


Nb removal rate = 5.3 µm/min

Total Nb removed during 10 min of BCP = **53 µm**

Total Nb removed during 9 min of BCP = **47 µm**

Results fine grains cavity (June 2010) cont

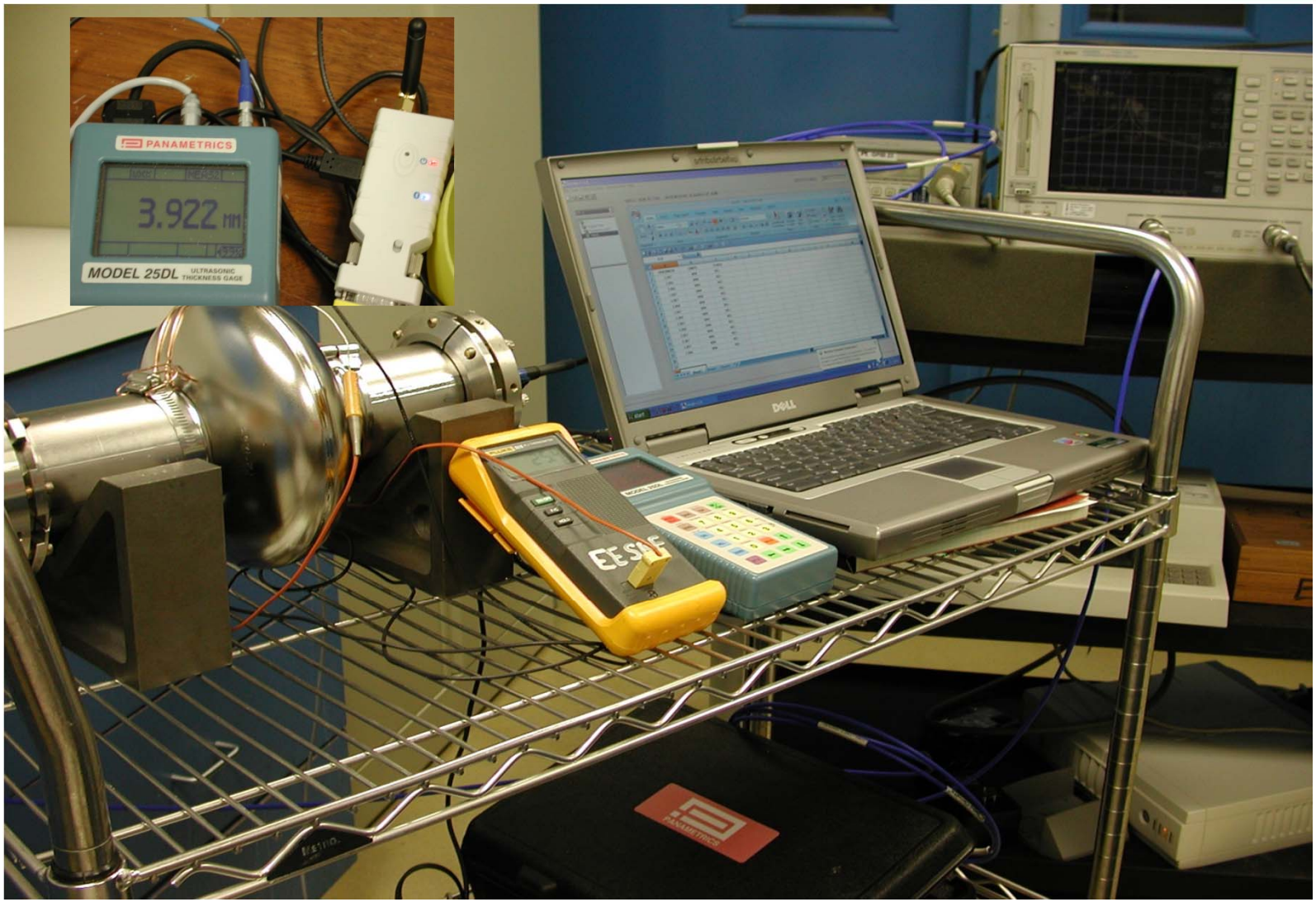


After BCP freq= 1482.4 MHz

Δ freq = 1482.85 - 1482.4 = 0.45 MHz

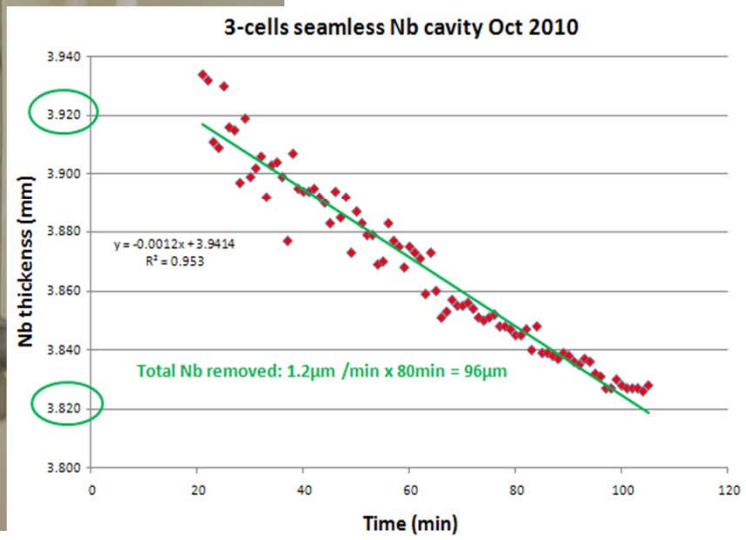
Nb removed =450 kHz/(11 kHz/µm) = **40.9 µm**

Wireless transmission of US measurements



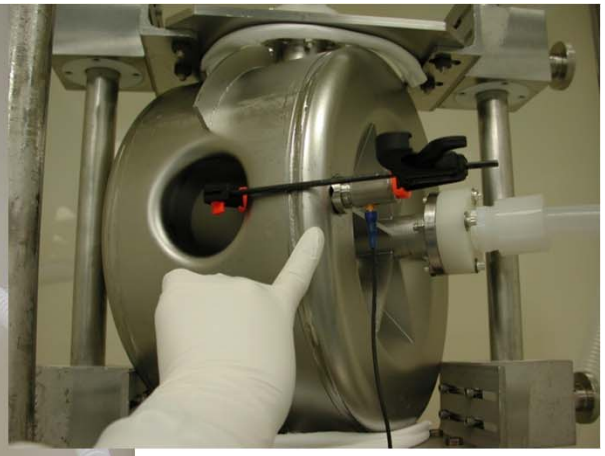
1500 MHz single cell with probes attached for frequency measurements after BCP.

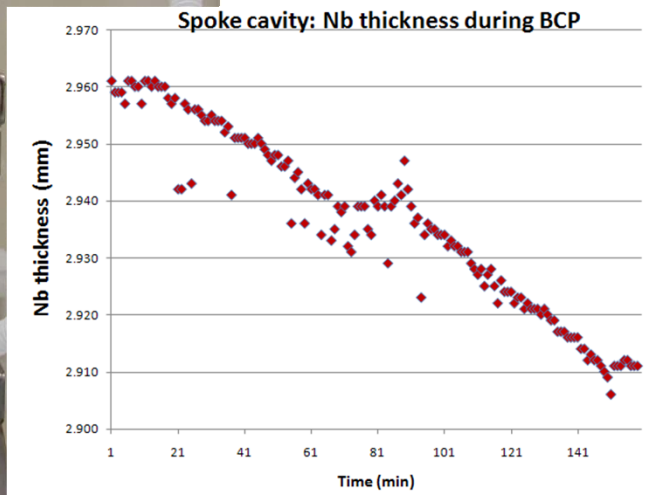
Seamless fine grain Nb 3-cells cavity Oct 2010



In situ Nb thickness measurements with wireless data transmission during BCP.

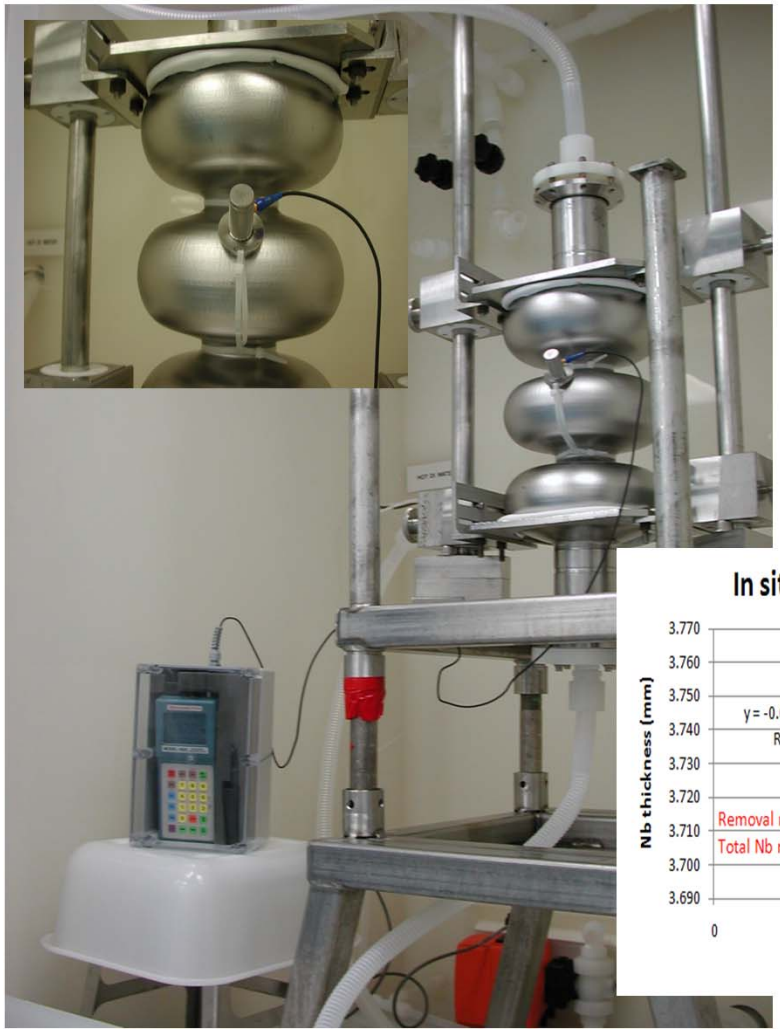
Spoke cavity July 2010

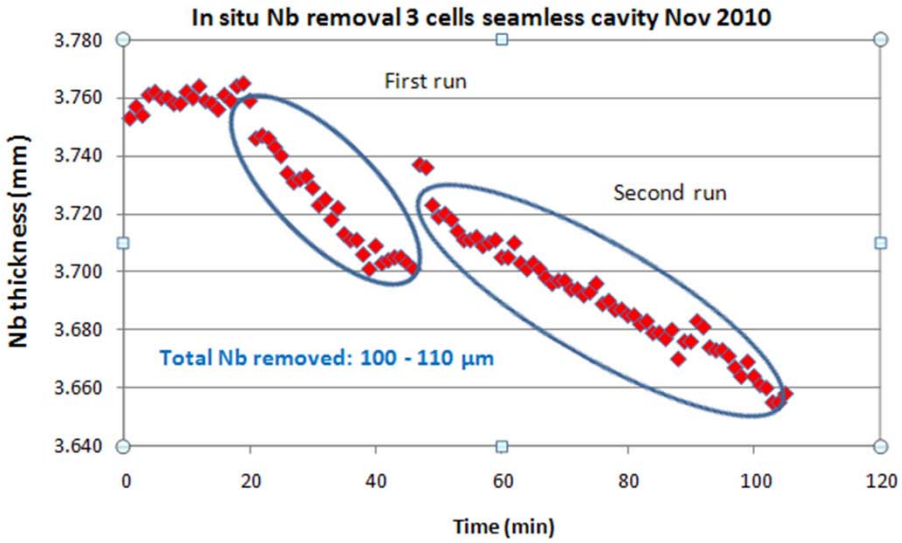


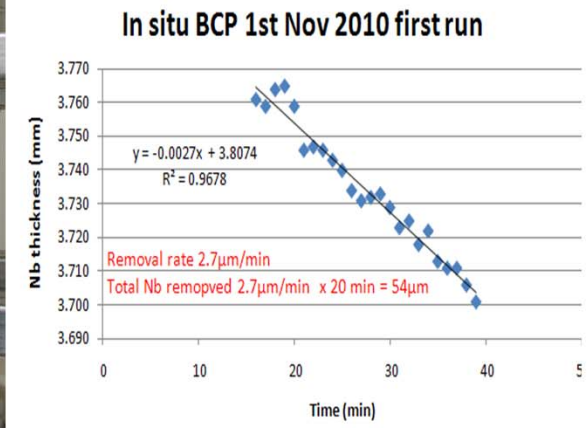


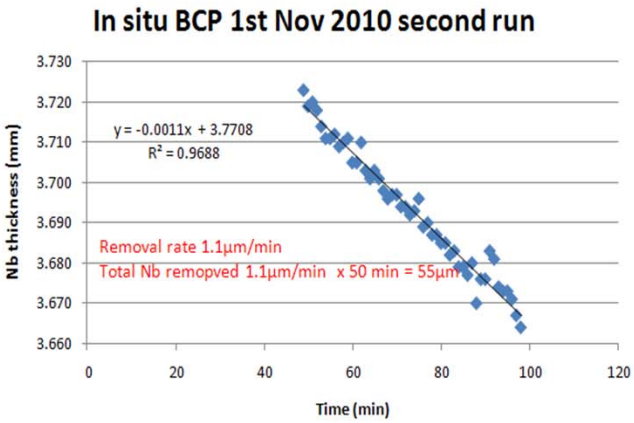
In situ Nb thickness measurements on a spoke cavity during BCP.

Seamless 3-cells cavity Nov 2010







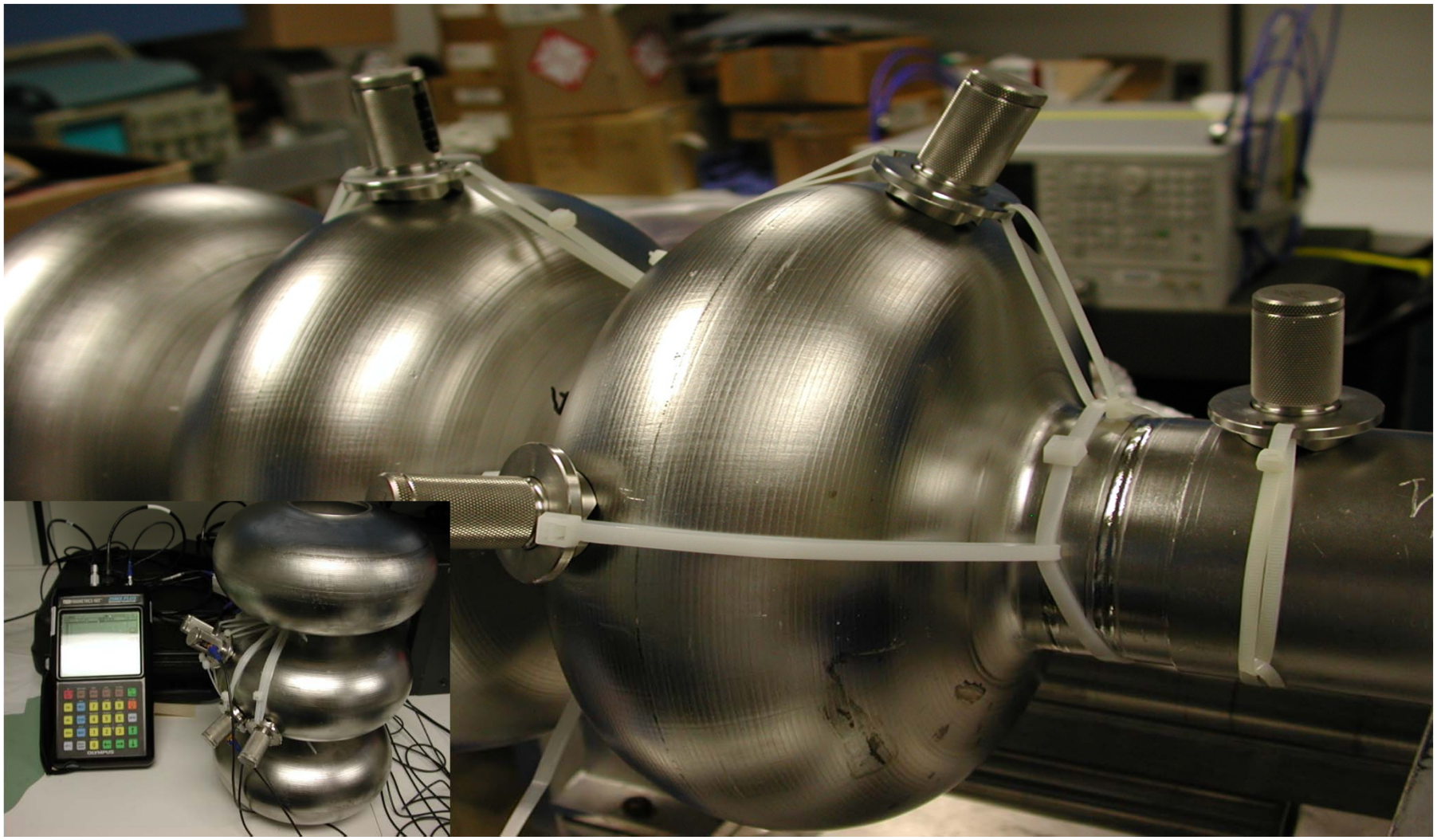


Seamless 3 cell cavity with ultrasonic probe for thickness measurements during BCP.

Still to be done

- Data acquisition program (LabView).
- Multichannel ultrasonic measurement instrumentation (8 channels?).
- Fixture for the US gauge on the multicell cavity.
- Water proof box for instrument and wireless transmitter and fixture of the box on the cavity stand.
- Ultrasonic Nb thickness measurements during PCB on a multicell cavity.
- Study of Nb removal rate as function of acid strength and temperature.

Multi gauge setup



3-cell seamless cavity with probes attached for simultaneously thickness measurements.

Conclusions

-In situ ultrasonic Niobium thickness measurements during BCP - **can be DONE** – consistent results were obtained for Nb removal as measured with the ultrasonic device or estimated from frequency shift measurements.
-It is an efficient direct method for in situ Nb thickness measurements. Saving in measurement time.
-Wireless transmission of facilitates data acquisition in controlled environment.

Acknowledgements: Tony Reilly, James Davenport and Teena Harris