Lithium lens and window tests

1. Possibility of Liquid lithium lens
2. Plan of window test with liquid lead target at KEKB ring tunnel

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With help of Pavel Logachev (BINP, Novosibirsk)

Lithium lens for positron production system by A. Mikhailichenko (EPAC08, WEPP157)

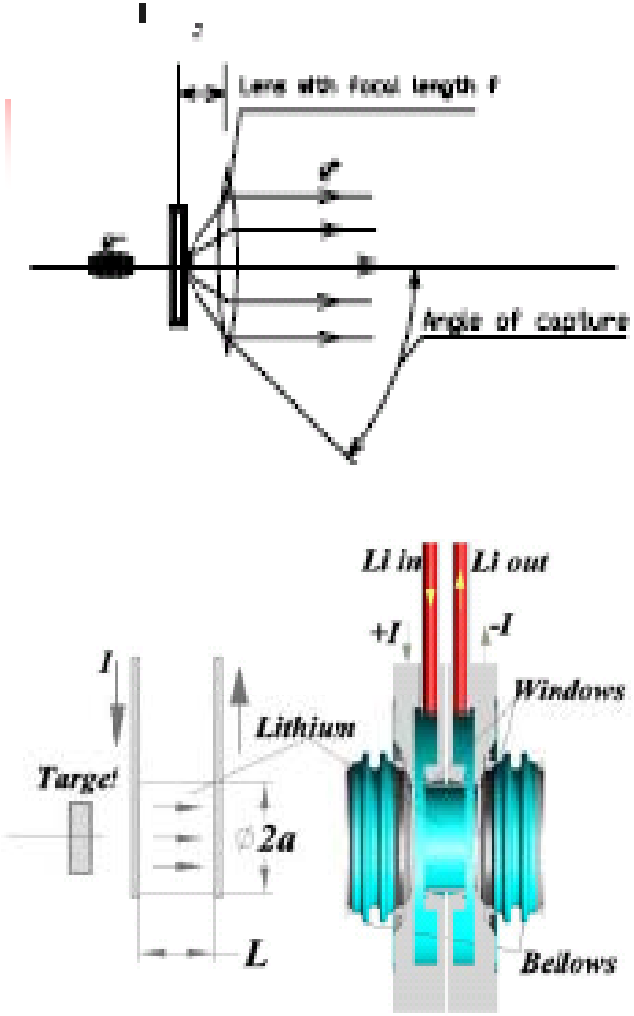


Figure 1: Lithium lens concept, left. At the right the transverse cut or suggested lens design is represented.

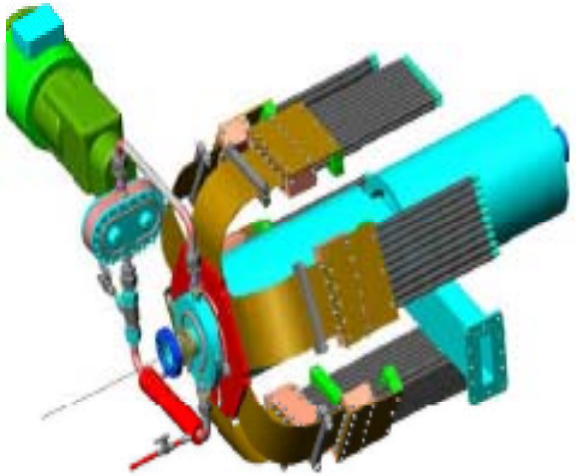


Figure 4: The lens is shown installed right after the liquid metal target [2] in front of accelersting structure. Ti rim could be used here as well.

Table 1: Parameters of conversion system with Lithium Lens recommended for the best polarization performance

General parameters	
Energy of primary beam	~150 GeV
Undulator period λ	10-12 mm
K factor, $K = eH\lambda/2\pi/mc^2$	≤ 0.4
Undulator length	≤ 200 m
Efficiency, e^+/e^-	1.5
Polarization	≥ 60%
Target	Tungsten 1.75 mm
Energy of quanta	~18 MeV
Distance to the target*	180 m
Lens	
Feeding current, I	<150 kA
Field at surface, H_m	43 kG
Gradient	≤ 62kG/cm
Pulsed power	~200kW
Average power	~4kW
Pulsed duty, τ	<4msec
Lens diameter, $2a$	1 cm
Length, L	0.5-1 cm**
Axial pressure, P_0	74atm (for L=0.5cm)
Temperature gain per pulse	≤ 170°C at 150kA

*Calculated from the end of undulator,
**Under optimization for final λ and K.

BINP tested 500 kA lithium lens with the following parameters: lens diameter - 20 mm, length - 200 mm, max current - 500 kA, Pulse duration 100 μs (Flat top).

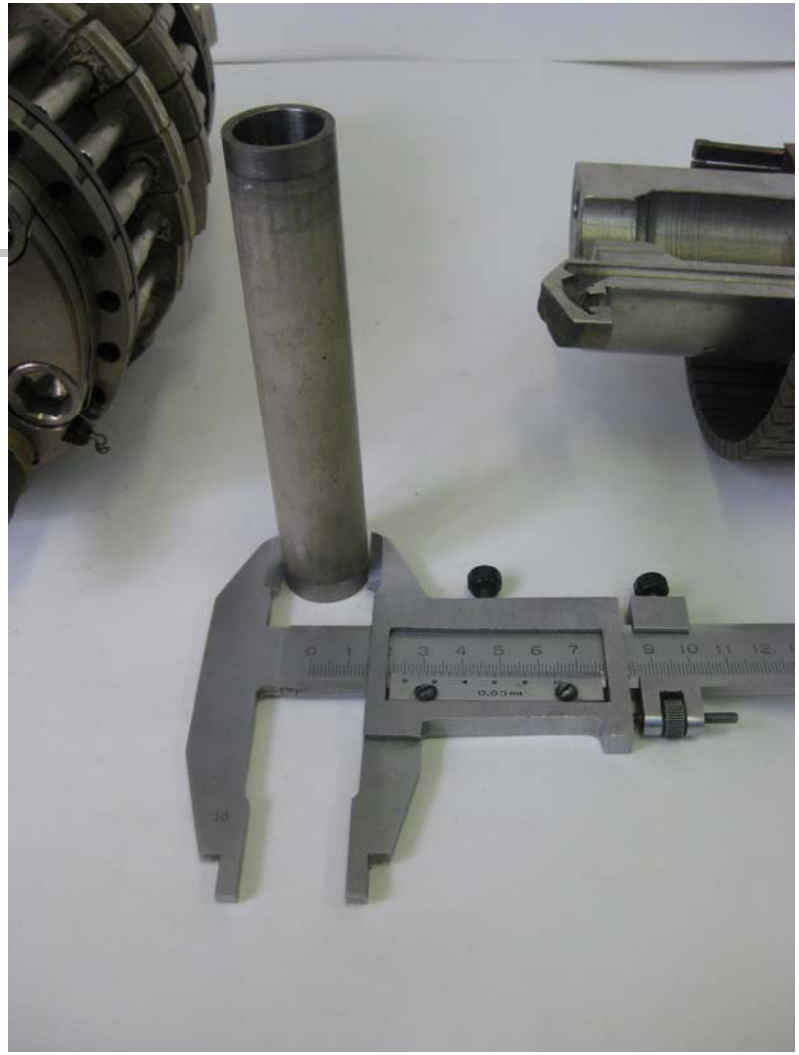
The test was OK - only with static pressure of liquid lithium - 3.5×10^7 Pa, (Shock wave pressure during the pulse is additional 3×10^7 Pa).

Static pressure is necessary to avoid liquid lithium boiling during the pulse. Due to static pressure the lens pipe should be made from pure titanium,
(not titanium-aluminum alloy! - lithium will leak through the alloy pipe – this pipe wall thickness is 2 mm),
Input and output windows is pure titanium parts with 30 mm thickness. The supplying pipes can be stainless steel with 2 mm walls. The key point is up to 10^8 Pa shock resistant pipes joints for liquid lithium.

The view of the assembly from the beam input.

This is the assembly of liquid lithium lens. On the top of the device you can see the connections for high pressure liquid lithium, in the middle part - 500 kA connections.

This is the cut part of the lens prototype – main anti-pressure chamber.



Main titanium pipe

The system of 500 kA contacts - aluminum oxide coating insulation is in the middle.

500 kA pulsed transformer

This lens was designed for antiprotons collection in FNAL at high energy of primary proton beam - better than electron beam. This is a prototype, also BINP made Be windows 10 mm thickness. All the device was cooled down by liquid lithium. It was pumped through the device and heat exchanger by electromagnetic pump at static pressure of 3.5×10^7 Pa. The max repetition rate was 2 Hz, difficulties with cooling down of not windows, but all the device. Pavel does not know the solution for windows in ILC case at present.

This prototype was designed for high energy proton beam - about 2 - 1 Hz - no problem with windows.
Windows (in ILC) all the time is a big problem, also Pavel thinks BN is the first candidate to test.

High pressure liquid lithium, 500kA feed.

Difficult to disassemble due to fire problems with lithium and water vapors.

Anti-pressure chamber is necessary in order to provide a reasonable inside and outside pressure balance for the main lens pipe during operation.

The main pipe is pure titanium, covered by aluminum oxide. Aluminum oxide covering is used as main insulation between parts of the device.

I think we have no solution about window for usual ILC beam. So, we need the window test with beam.

Target : Liquid Lead

Liquid Lead Target

Question: Can Liquid Lead Target (& BN window) survive the 3000-bunch-creation in 1 m sec?

Answer: No

BN window is OK against shock wave. BN window is broken by heat. Lead evaporates.

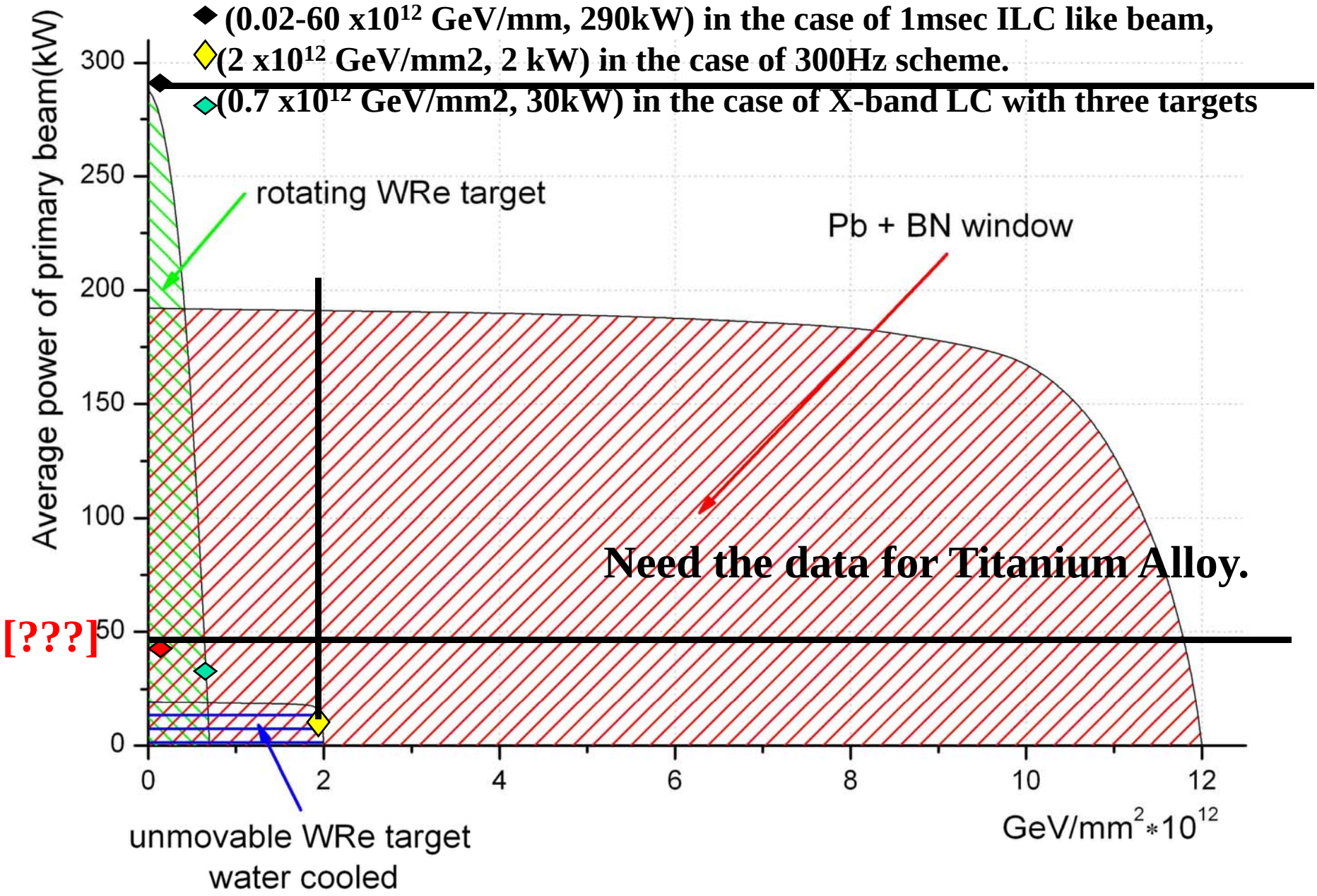
For 300Hz scheme,

BN window is OK for 100 bunches.

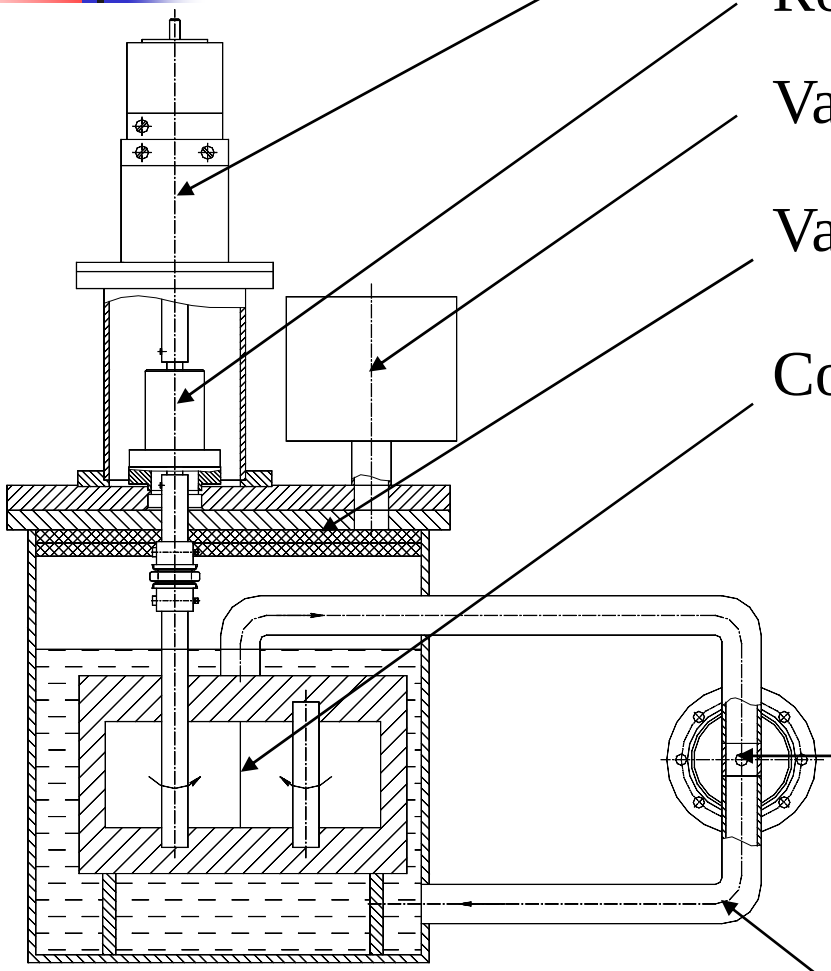
Lead dose not evaporate with 100 bunches.

Lead move 32 mm in 3.3 msec, then heat is removed. (speed of lead = 10 m/sec)

BINP tests of the liquid lead target with BN windows are in progress. Up to now they run 600 h, and plan to stop and see what happens with windows. They will have a result of the first run in 2 weeks. (I guess they use 30kW (60keV, 500mA) electron beam.)


(0.017-50 x10^12 GeV/mm, 40kW) in the case of Undulator scheme
(0.02-60 x10^12 GeV/mm, 290kW) in the case of 1msec ILC like beam,
(2 x10^12 GeV/mm2, 2 kW) in the case of 300Hz scheme.
(0.7 x10^12 GeV/mm2, 30kW) in the case of X-band LC with three targets
Average power of primary beam(kW)
300
250
200
150
100
50
0
rotating WRe target
Pb + BN window
Need the data for Titanium Alloy.
[???]
0
2
4
6
8
10
12
GeV/mm^2*10^12
unmovable WRe target
water cooled

Scheme of the prototype of liquid lead positron production target.



Driving motor

Rotating vacuum feedthrough

Vacuum pump

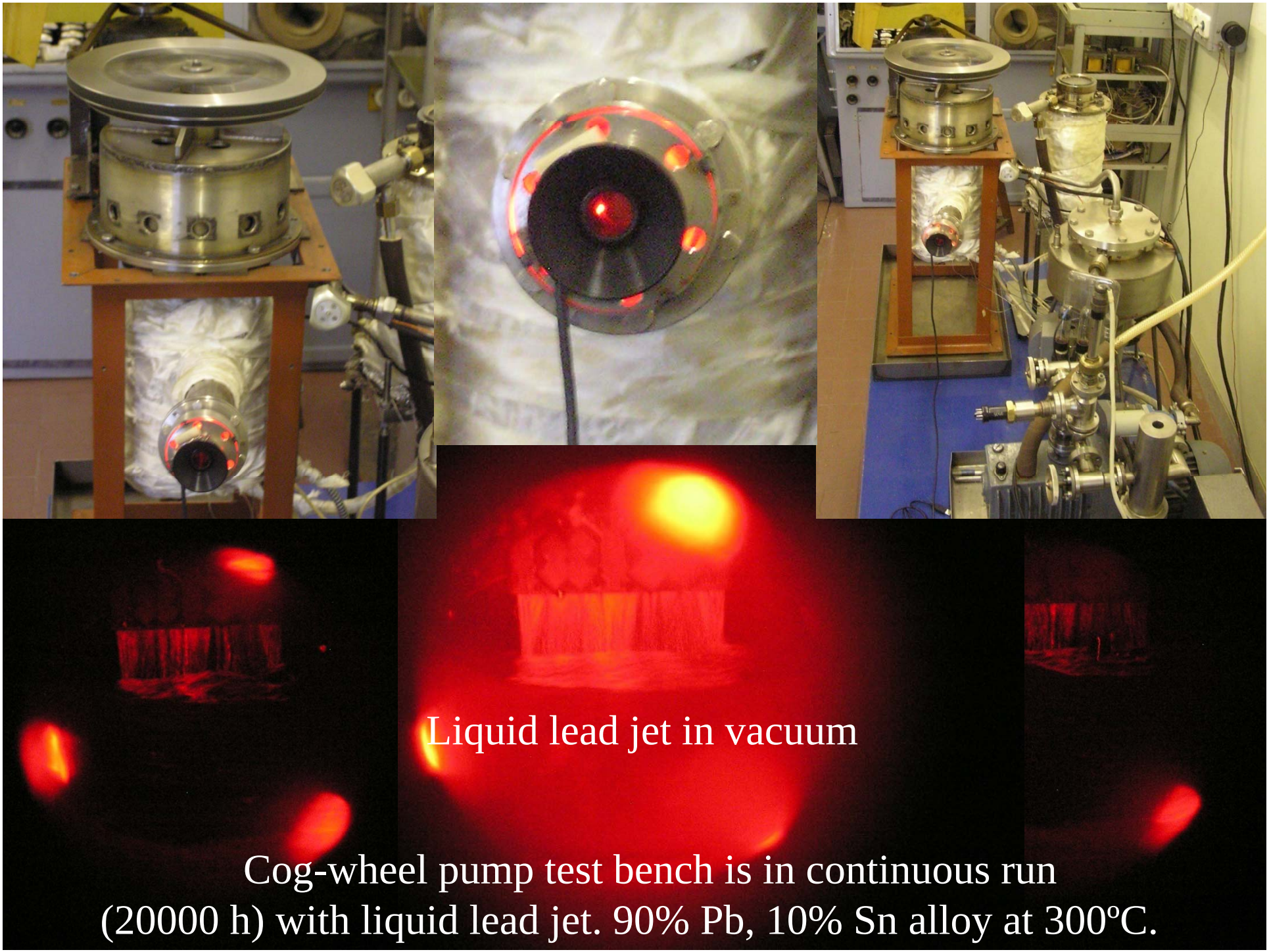
Vacuum tank of the system

Cog-wheel pump

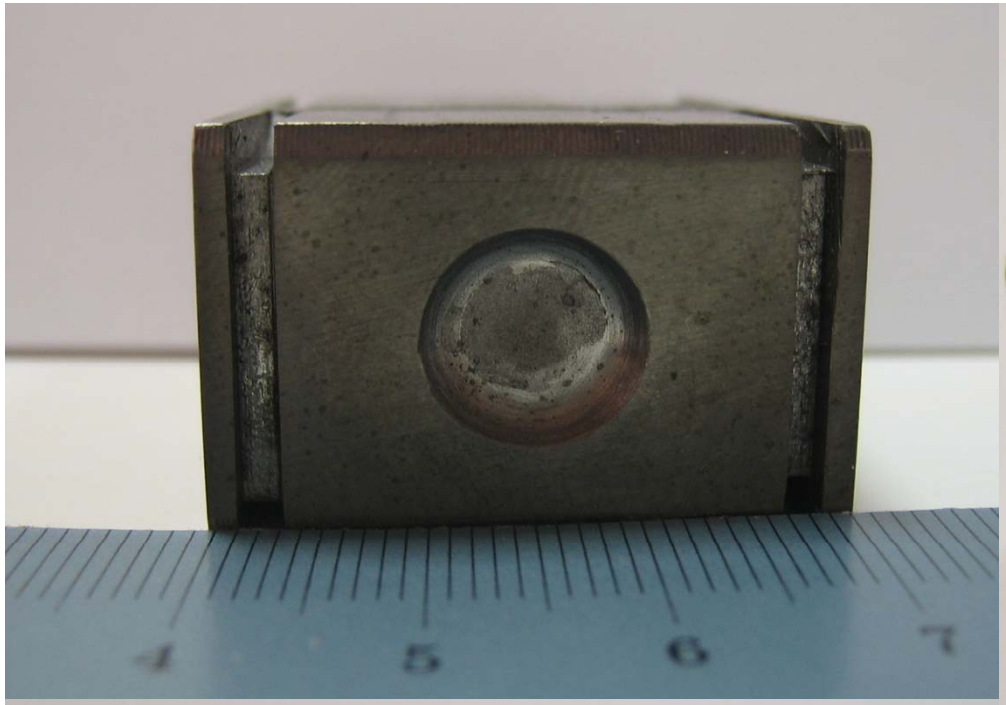
Target head

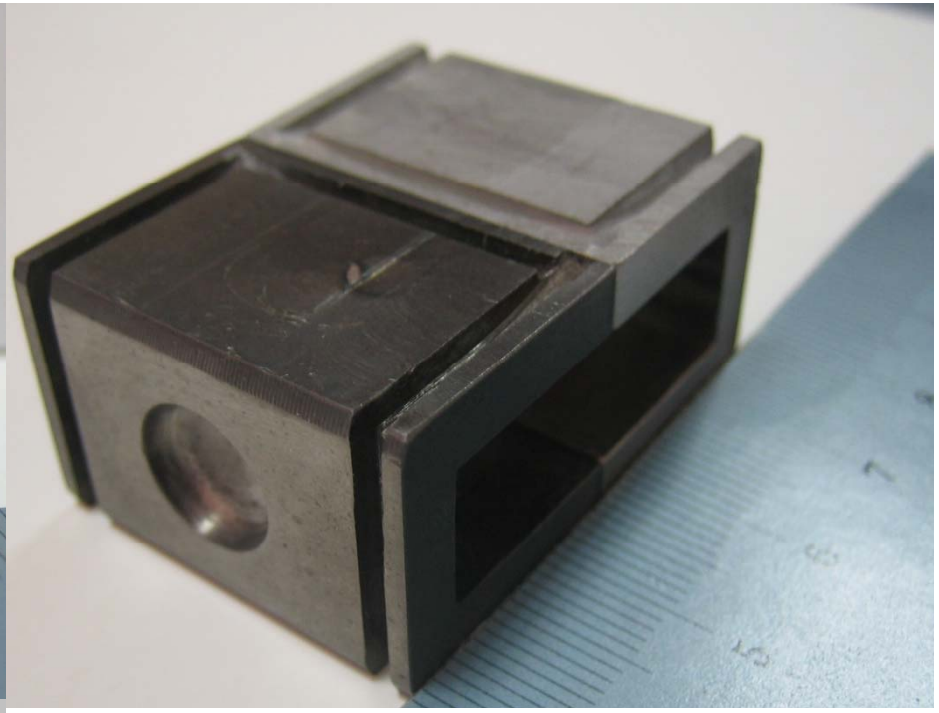
Liquid lead transport tubes

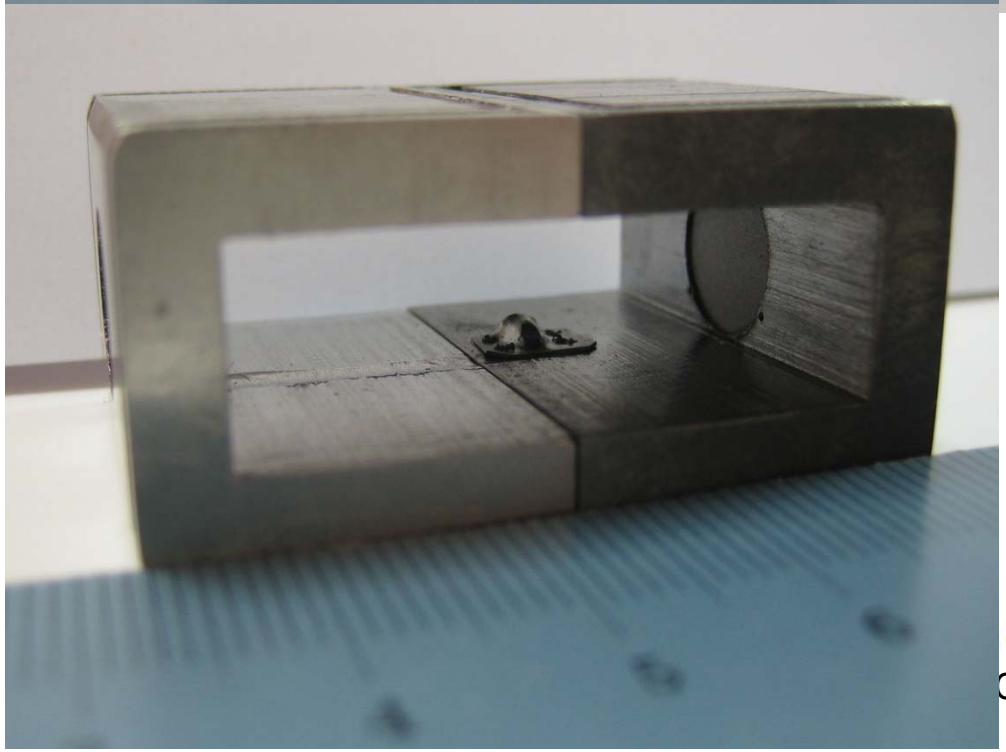
The parts of liquid lead cog-wheel pump



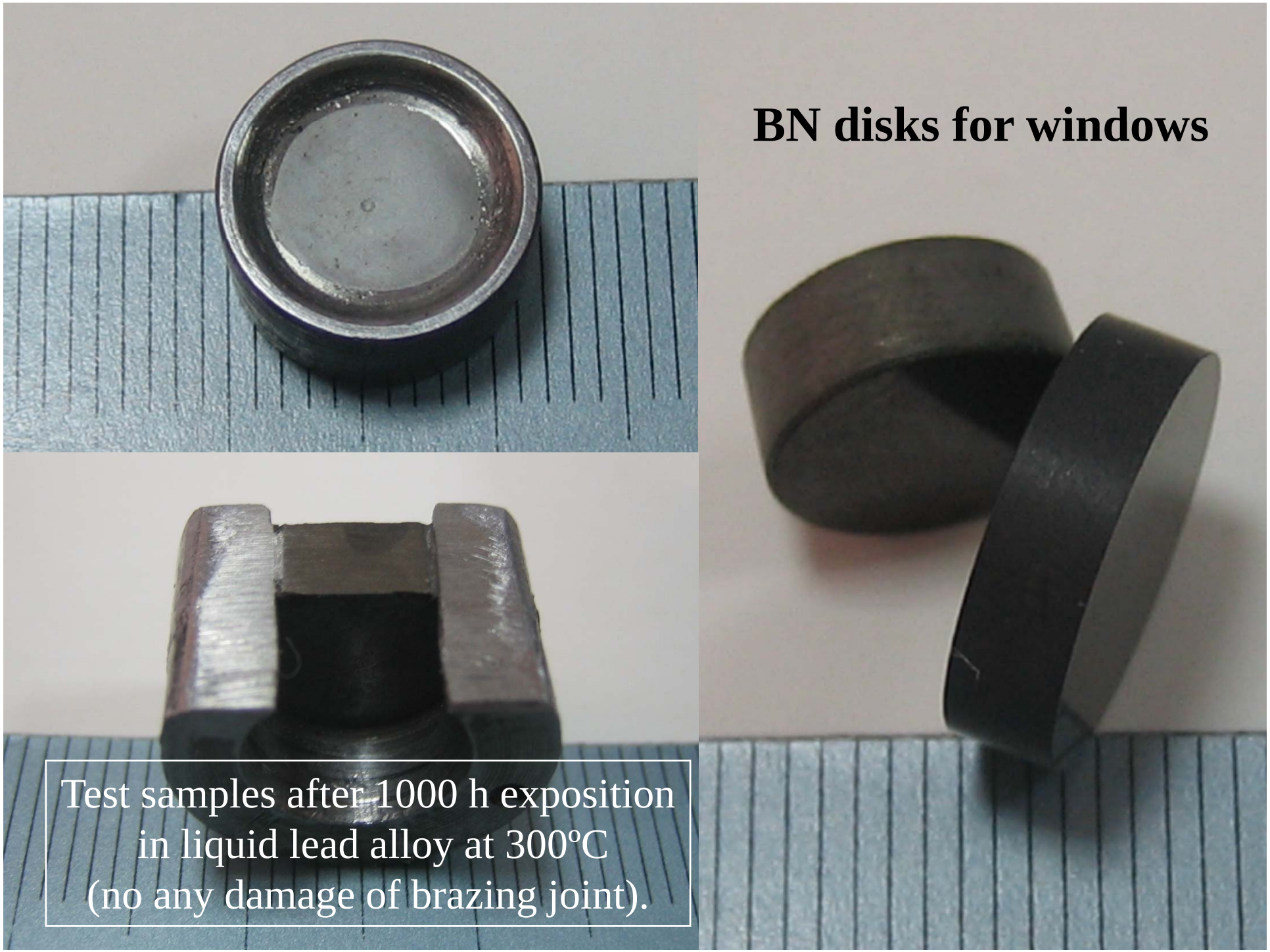
Cog-wheel pump test bench is in continuous run
(20000 h) with liquid lead jet. 90% Pb, 10% Sn alloy at 300ºC.







Prototype of target head with BN windows.


BN disks for windows
Test samples after 1000 h exposition
in liquid lead alloy at 300ºC
(no any damage of brazing joint).

The present stage of BINP activity in liquid lead target development.

- 20000 h of liquid lead contour successful run with cog-wheel pump has been reached (90% Pb, 10% (mass)Sn alloy, 300ºC).
- The test of window braising technology successfully finished but BINP found problems with quality of the boron nitride windows brazing after 500 hours operation with beam.
- The prototype of liquid lead positron production target is under commissioning of 2 weeks beam operation.

Plan of window test with liquid lead target at KEKB ring tunnel

Need the test of BN window and liquid lead target with KEKB Ampere beam. Also, we need small hall to install the test system.
The prototype of liquid lead target system is specially designed for output window destruction test on KEKB.
But we need the proposal to submit KEKB PAC and it is not ready.
I guess we need about 2 years to prepare and evaluate the performance of the window and the liquid lead target after approval of our proposal by KEKB PAC.