KEK Injector Linac Present Status and ScandiNova Modulators

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ScandiNova Users Meeting 2024

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Introduction

Since we are a new comer in Scandinova User Meeting community.. .

Name of Lab. and its purposes

- KEK(Ko Enerugii Kasokuki kenkyu kikou, 高エネルギー加速器研究機構, Jap)
  High Energy Accelerator Research Organization, (en)
- One of the major International laboratories conducting various high energy physic programs as well as operating light sources.
- The facilities are located in two campus, Tsukuba(Electron) and Tokai(Proton synchrotrons).

KEKB Injector LINAC 8GeV electron/4GeV positron linac to provide all the synchrotrons in Tsukuba.

For detail (currently conducting experiments, so on) visit our WEB site below:
https://www.kek.jp/en/

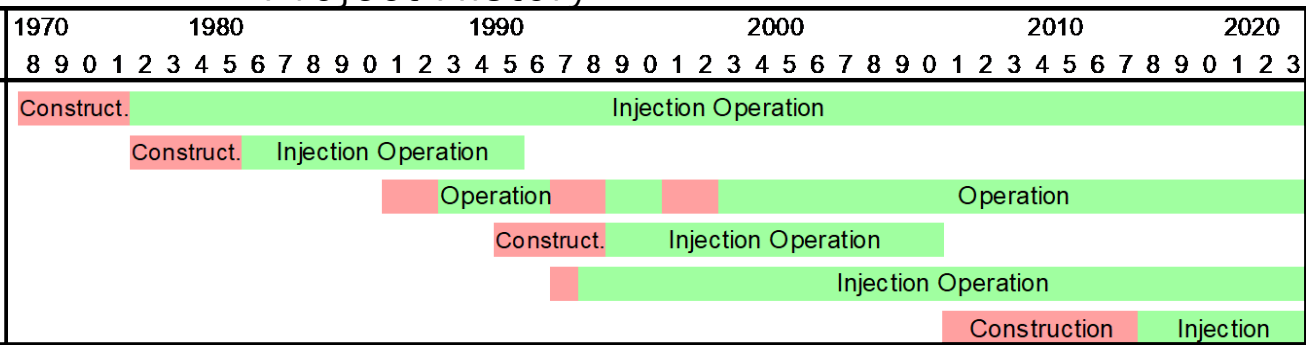
Why I attend this meeting..

- Report very recent activity with Scandinova modulator K-300 in KEKB Injector.
- Share various information and/or experience on running the RF facility with Scandinova modulators

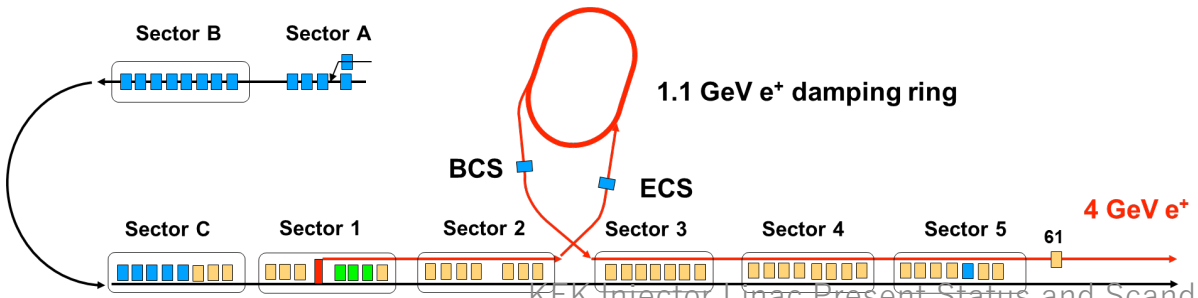
Injector Linac

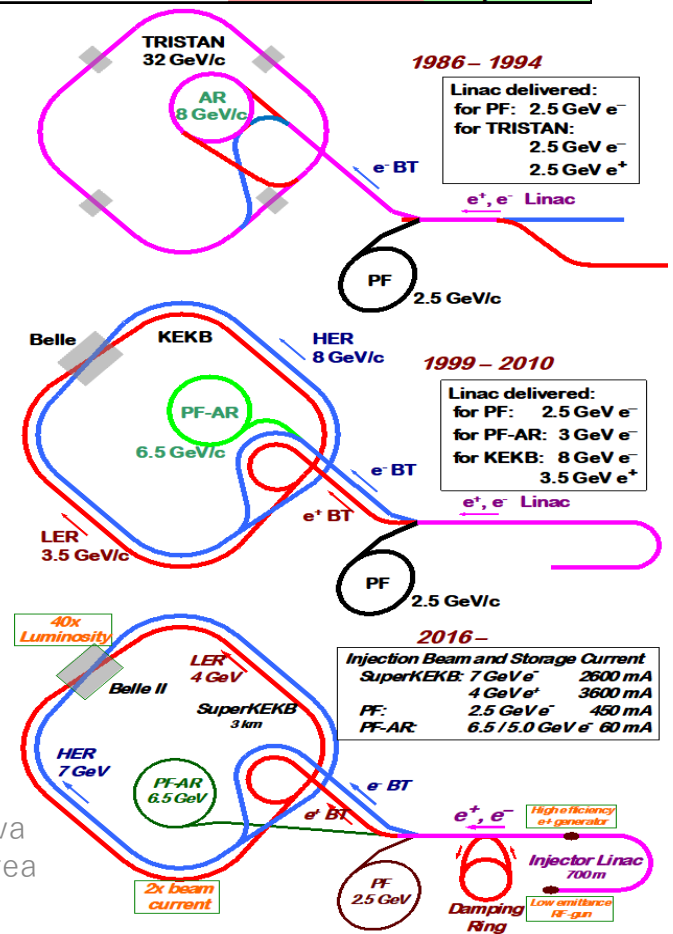
Project History

Project	Injection Energy	JFY Exp. Energy
Photon Factory	2.5 GeV	2.5 GeV
TRISTAN	2.5 GeV	32 GeV
Slow Positron	2.5 GeV - 55 MeV	0.1 - 35 keV
KEKB	8 / 3.5 GeV	8 / 3.5 GeV
PF-AR	2.5 GeV - 6.5 GeV	5 - 6.5 GeV
SuperKEKB	7 / 4 GeV	7 / 4 GeV



- 42 years of operation
  - for particle physics and photon science
    - Started with one of first dedicated light sources, PF
    - and the highest energy collider, TRISTAN with SRF
  - Long-term multiple disciplinary operations
  - Still many devices from the first generation





RF power source in KEKB Injector

The keywords to view KEKB Injector power sources briefly:

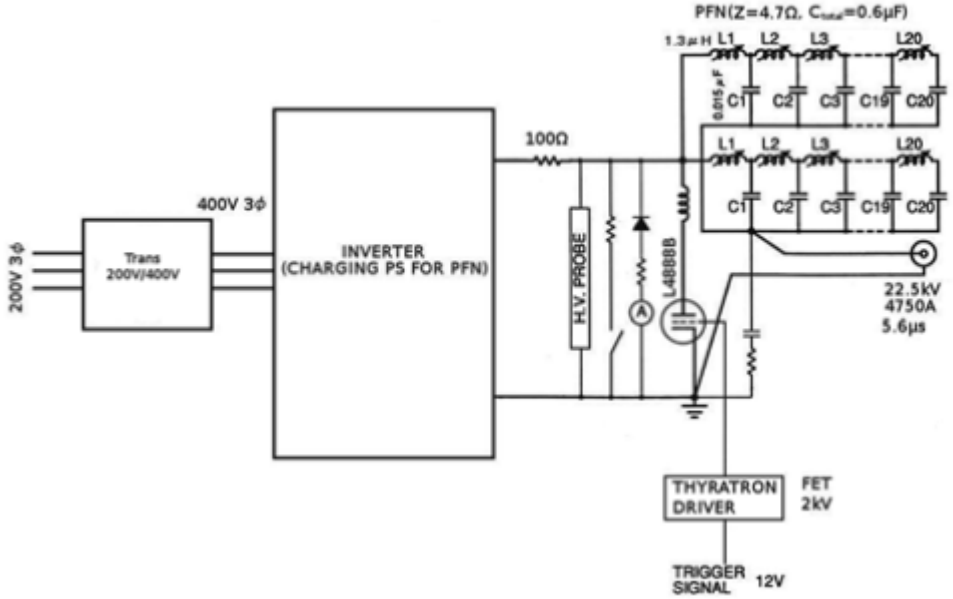
- S-band (2856MHz) ,
- 1RF unit consists of 1Mod+ 1KLY with four 2m L TW accelerating structures(E gain =160MV/unit).
- Modulators: equipped PFN and its charger, Thyratoron switch. Max charging Voltage is 45kV, Rep rate 50Hz. Pulse width 5.6us (Flat top 4us).

- Klystron (Max power 50MW, E3730A& PV3050) -> Meets K-300 modulator spec.

- Stability
  - timing jitter(Thy) ~ 10ns or less
  - peak volt fluc, pulse-to pulse <0.2%
  - <0.5%/Hr
- Pulse flatness <0.3%(p-p over 4us)

Current RF power source in KEKB Injector

1. PFN
2. Inverter charger
3. Thyratron switch



Spec (RF Parameters) KEKB Injector

Frequency	2856	MHz
Peak power	50	MW
Average power	10	kW
Pulse width	4	us
Beam Voltage	310	kV
Perveance	2.1	uP
Gain	51	dB
Efficiency	45	%

Klystron Specifications

PFN Charging voltage	45	kV	Max
Output voltage	-22.5	kV	Max
Output impedance	4.7	Ohm	
Load impedance	4.7	Ohm	
Pulse width(FW)	5.6	us	
Flat top	4	us	or more
pulse rising time	1	us	or less
repetetion rate	10	pps	Min
repetetion rate	50	pps	Max
pulse flatness(p-p)	0.3	%	or less
pulse voltage stability	0.2	%	pulse-to-pulse
pulse voltage stability	0.5	%	/hr, or less
pulse flatness(p-p)	0.3	%	or less

Modulator specifications

Test station T3: K-300

March 2023　Proposal:
At most two K-300 modulators are available for performance test in KEK. How about running them in KEKB Injector?

KEK response:
Found K-300 with Canon E3730A tube looks well fit to Injector.

It seems too “brave” go forward along the proposal right away because there is no chance to stop beam operation of Injector which is highly responsible for the huge amount of physics programs on going (in the accelerators downstream).

Therefore KEK proposed “back” as

1. Run a single K-300 modulator at our test station, T3, instead of settle it down in Injector.

2. Just run it continuously, for long term , say, 6 months, day and night if allowed.

Both 1. and 2., it is a good simulation for K-300 Modulator in KEKB Injector.

-> The work started once we agree this idea.

K-300@KL_T3 Project Shedule 2023.9.27 proposed 10.18updated.

month	9	10					11				12				1					2				3			
week	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25
Preparation																											
delivery and installation																											
AC power connection			delivey Oct 11																								
Cooling water conection																											
								ScandiNova engineer																			
Assembling								at KEK Nov16～22																			
Kly mounting																											
									Kly Diode test																		
Waveguide conection																											
Operation																			baking WG								
RF conditioning																											
Long run																								long run			

K-300 delivered to KEK site,
Oct. 11, 2023

K-300 Spec

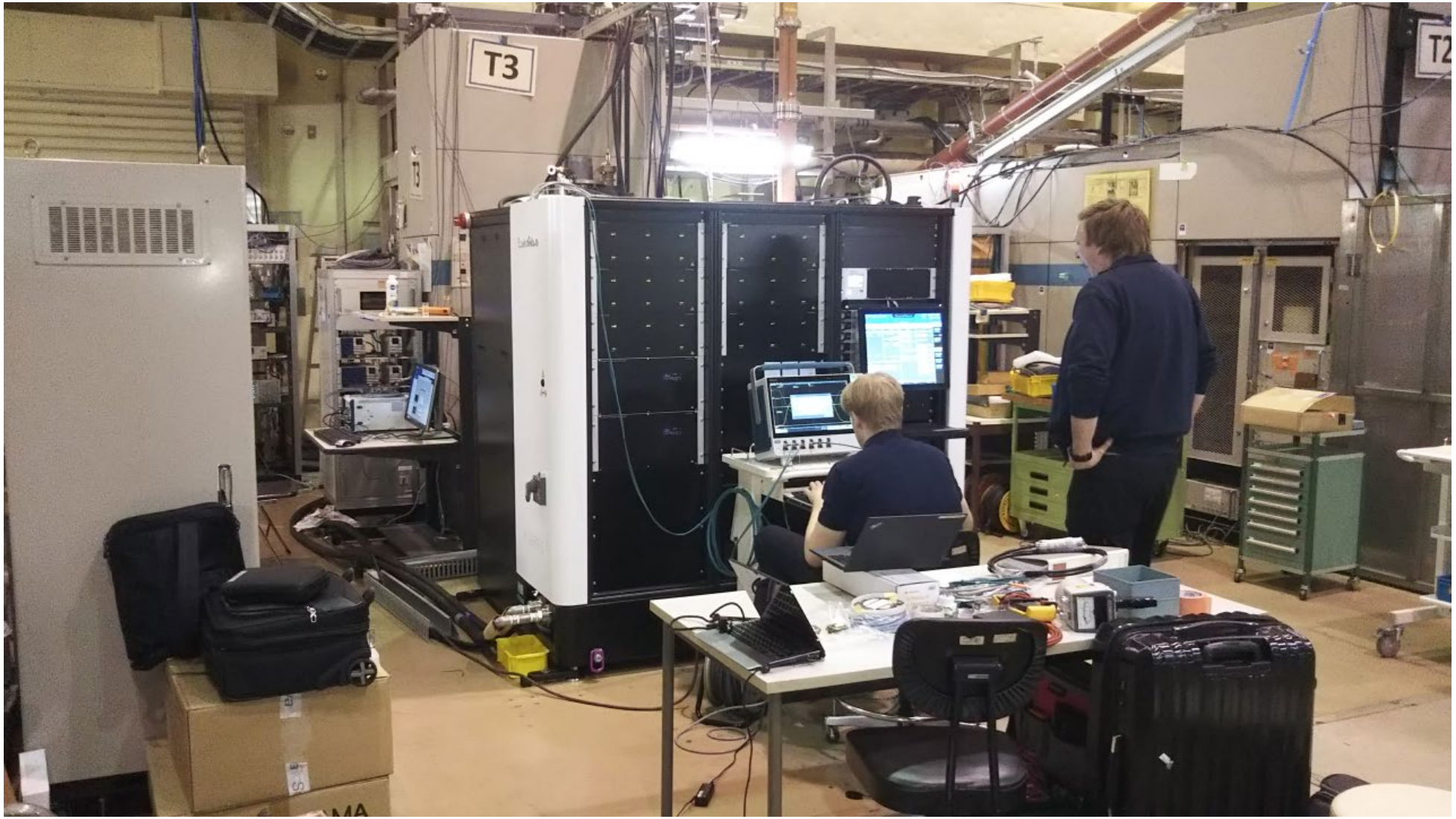
K-300 with “KEK customized” originally proposed is found to be not sufficient for 40MW RF output.

40MW ->
the maximum Klystron output in Injector LINAC operation.

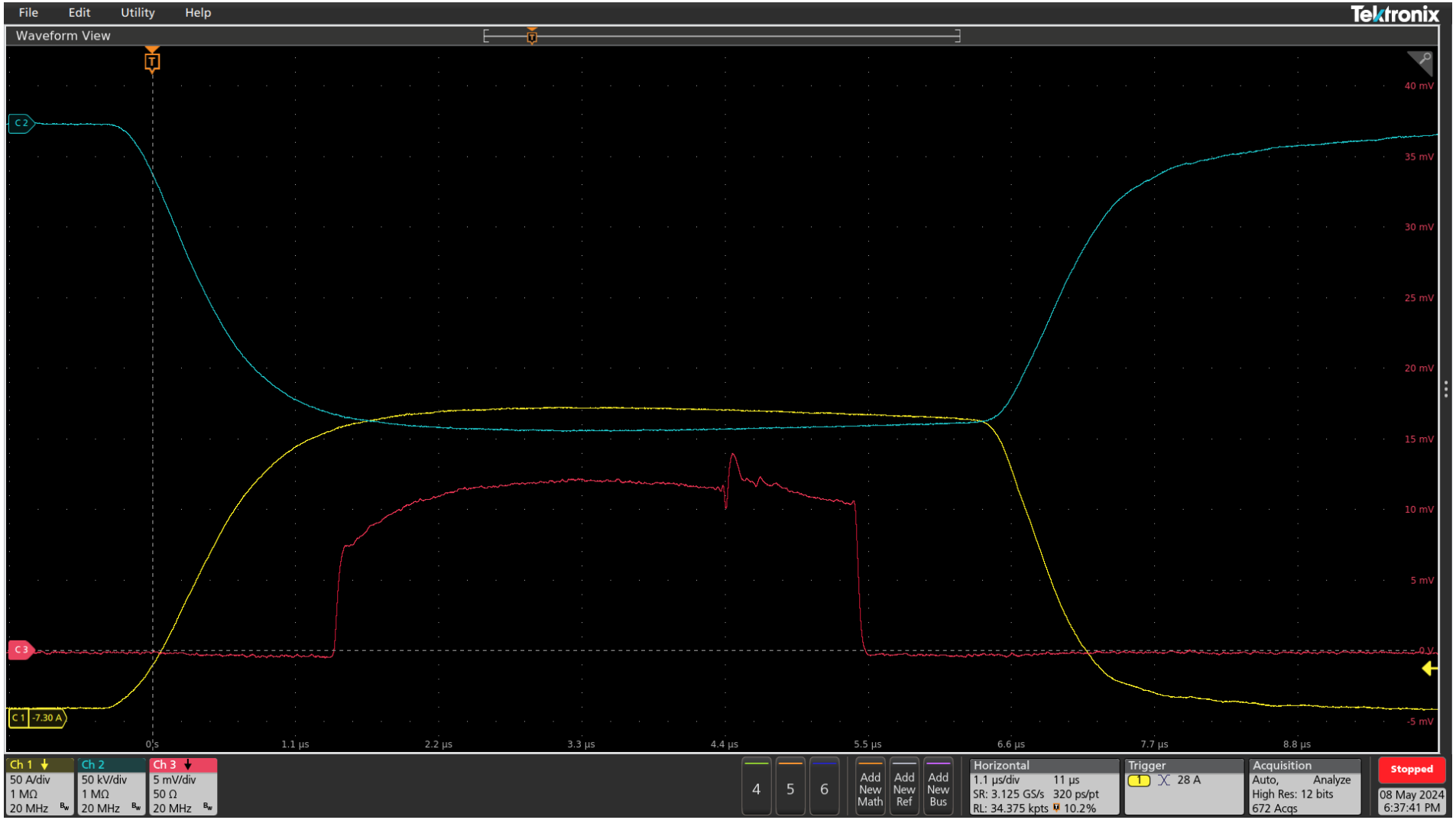
The secondary voltage was reinforced by changing the set ot TAP from the original (58) to new (64).
Also all the waveform tuning circuits elements were shorted and this makes the peak power of the tube push up to 40MW more.

モジュレータ仕様

		単位	仕様値	備　　考
クライストロン適合	型番		E3730A/PV-3050	
	RF ピーク出力	MW	50	50MW 実使用 40MW
	RF 平均出力	kW	10	10kW 実使用 8kW
パルス出力	モジュレータピーク出力	MW	87	122MW
	モジュレータ平均出力	kW	24	36kW
	ビーム電圧/電流 1	Kv/ A	280/310	標準値　最大値　320kV/380A
	繰返し周波数	Hz	50	
	RF パルス幅 (top)	μs	4.0	
	ビーム電圧平坦度 (dV)	%	≤ ±1.0	定格動作時, 平坦パルス部
	安定度	%	≤ 100ppm	RMS(定格 の電圧設定に対して).
	トリガーdelay	μs	~1.2	上図ご参照
	パルス間 jitter	ns	≤ ±4	参考値
	パルス幅　time　jitter	ns	≤ ±8	参考値
フィラメント出力	DC 最大電圧/電流	Vdc/Adc	20V/20A	クライストロンにより異なります
	電流安定度	%	≤ 1%	



K-300 running at Test station T3, KEK Injector test hall. Achieving 40MW RF output power, Apr.17 2024.
Now the station is under long-term running test.

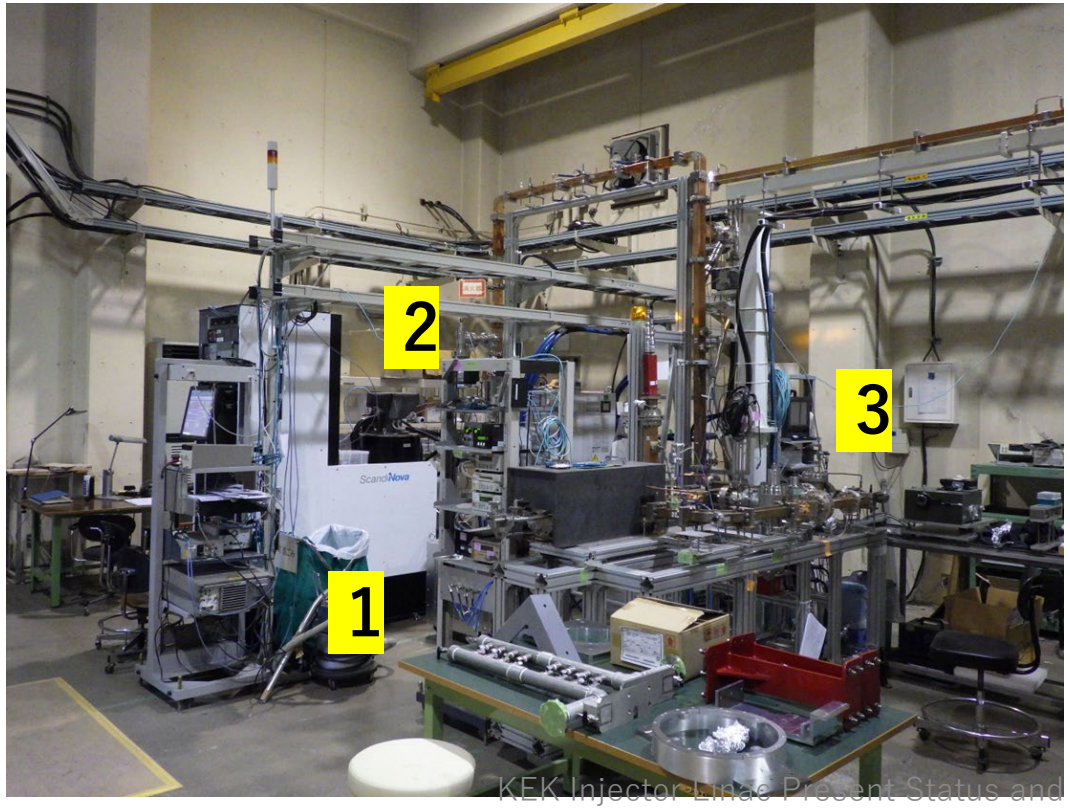


Waveforms on the display of the scope. Yellow: CT, Blue: CCVD, Red: RF KLY OUT. May 08 2024 K-300 running at CCPS 1265V 50pps. (300kV x 340A x 50pps; ~43MW peak output.),

Test station T8: K-100

We have one small Scandinova K- series modulator

Single K-100 modulator **1** with E37347 klystron (7MW output) **2** working as the power horse for the resonant ring **3** (RR. The max circulating power=150MW, S-band).



- Originally the RR shared its power source (kly 50MW) with another test stand next neighbor.
  The waveguide connection is changed time to time. **-> very inconvenient**

- Thus we made “Plan 2019”:
  Purchase
    K-100 modulator
    7MW small compact klystron

- Construct
        compact
        high duty (200pps)
   power source for RR.

- The facility was constructed 2019 -2020. It was kept idle recent years, but from last year we restart it.

- The purpose of RR/T8 station
  - Conduct RF Component high power testing using more than 100MW power.
  - Condition the RF windows (conditioning before actual installation).

We would like to know these technical properties:

	Items concern	evaluation
Electrical		
	Conversion efficiency(AC-> pulse)	
	Generation of electric (switch) noise when operation	
	Stability under noisy circumstances	
Running cost		
	Consumable parts	
Failures and recovery		
	HV trips	
	MTBF of important devices	

Some concerns about current RF system

For example,

Thyratrons

- We use 60 of these, some of these are regularly replaced in (most of the reason is due to the lifetime.)

- The price of thyratrons is gradually going up in last decade

- Need to find a good “ soft-landing solution “ for this issue.

Future perspectives

We are now first stage to be a user of Scandinova modulators.

We finish our “evaluation test K-300” in this autumn and hope to get the experience of long run which should be valuable for “future prospectives “.

We believe there is no technical issue to use Scandinova modulators. We need to know
how often the troubles in devices actually happen
and
how and when the system can be back to normal.

We should be interested in
- Consumable parts: Is it easy to replace?

- Spare devices or parts we should prepare and how easy we can get them.

- Repair and services.
Is there a service plant/office in Japan? Or you already have some plan?

Thank you