Recent activities at Tsinghua X-band High Power Test stand (TPoT-X)

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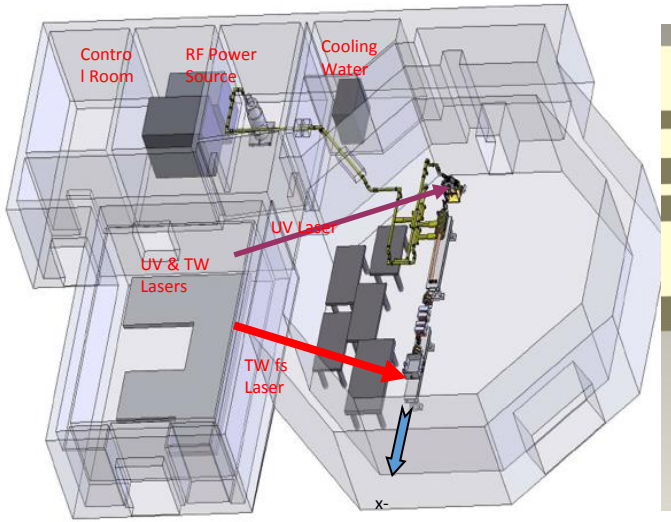
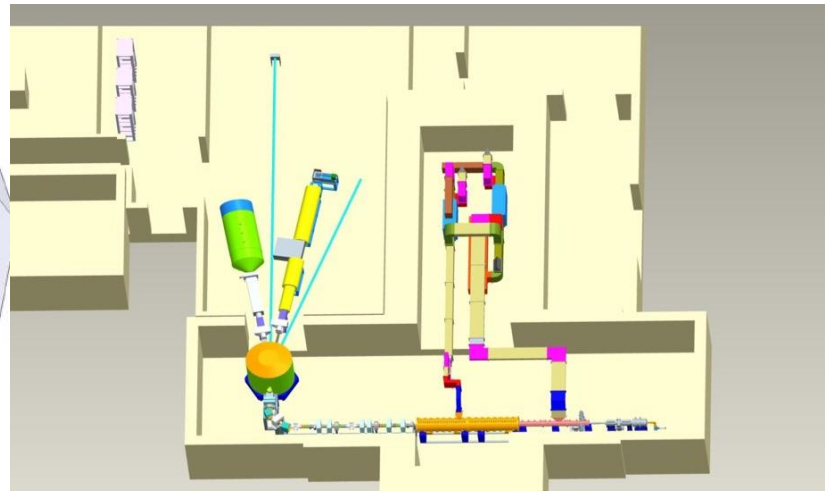
Background

- Accelerator Lab. In Tsinghua Univ., Beijing
- RF Structure (linac tubes) manufacturing since 1970s. >100 tubes/year
- Host of two beam lines
  - TTX (Tsinghua Thomson X-ray source), electron
  - CPHS (Compact Pulsed Hadron Sources) Proton
- X-band high-gradient activity started with collaboration with CLIC project. ~2009
- Production of HG structures
- Test stand at X and S-band

Tsinghua High Power Test-Stand

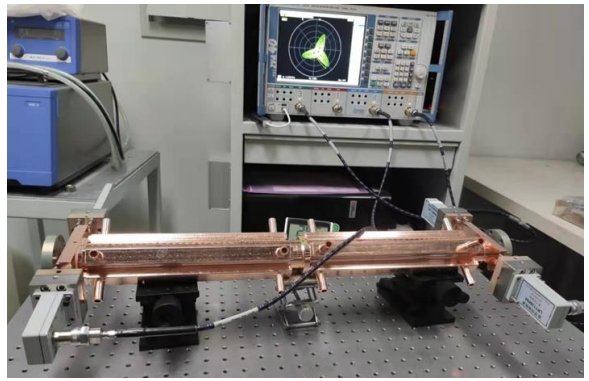


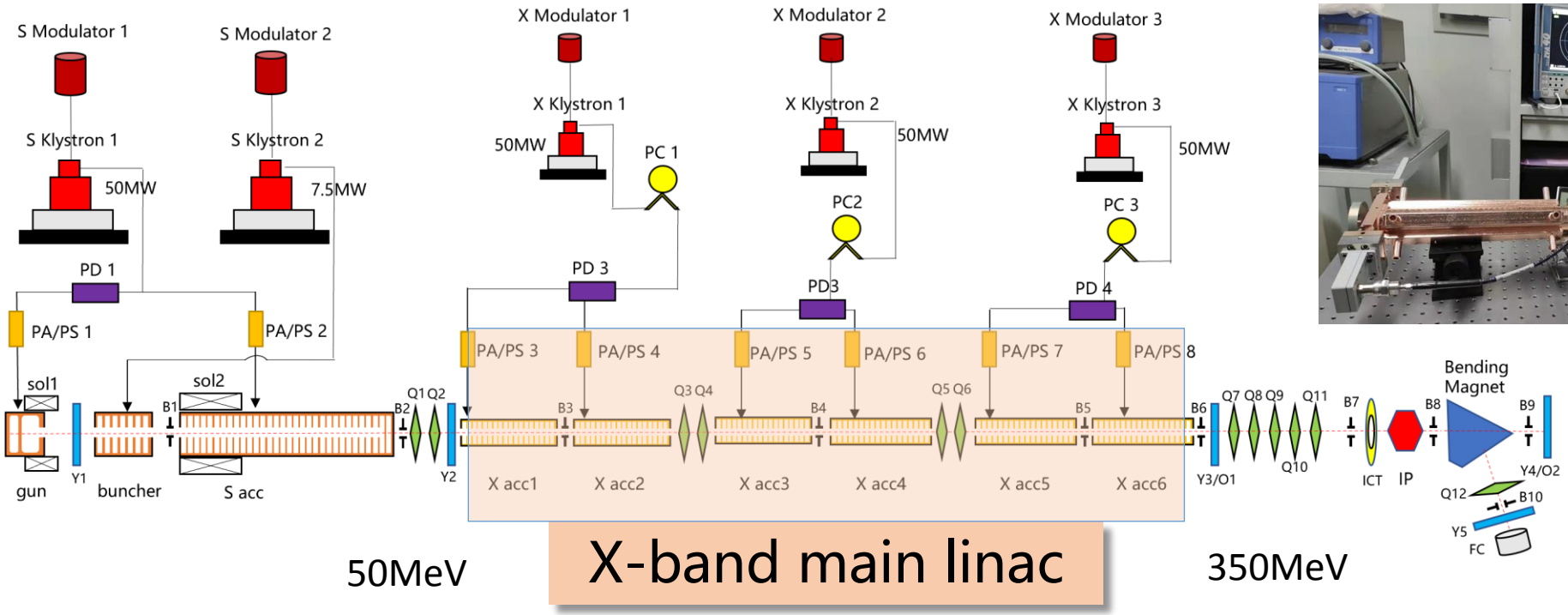


VIGAS: 350-MeV-linac based Inverse Compton Source

- Very Compact ICS Gamma-ray Source
- Total length < 12.5m: S-band injector and X-band linac at 80MV/m
- **Five-year (2021-2025) project**, beam-line under construction
- Beam available by the end of 2023

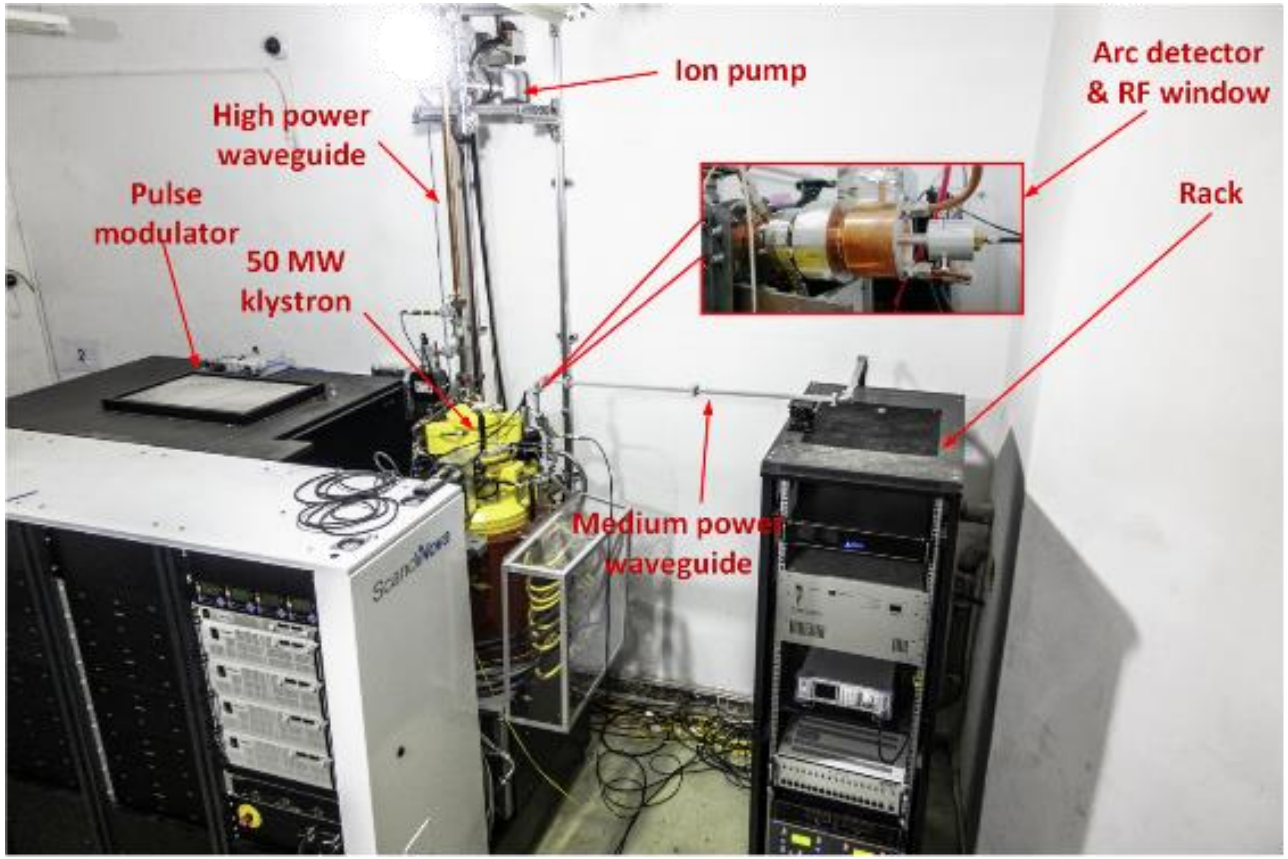
630mm X-band structure

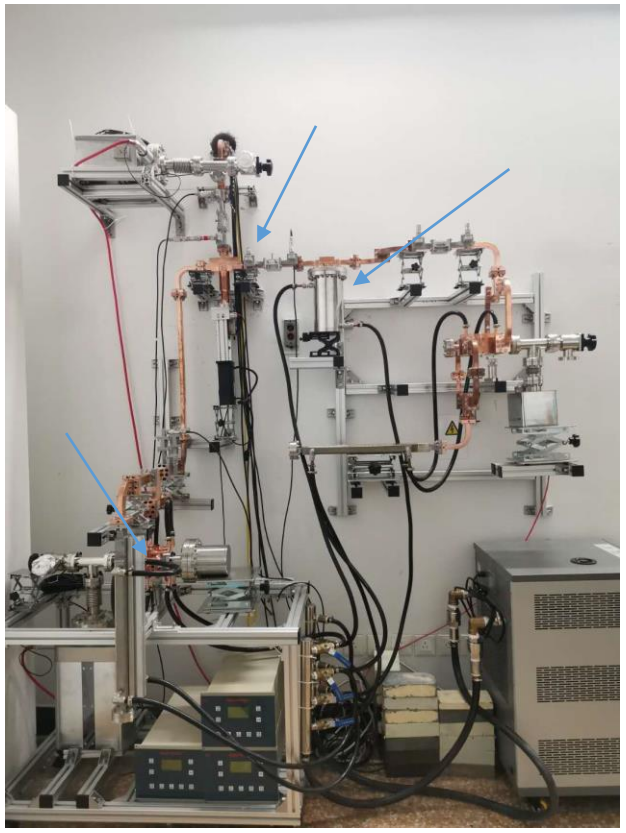




Background

- X-band High-power Test Stand started operation since 2018



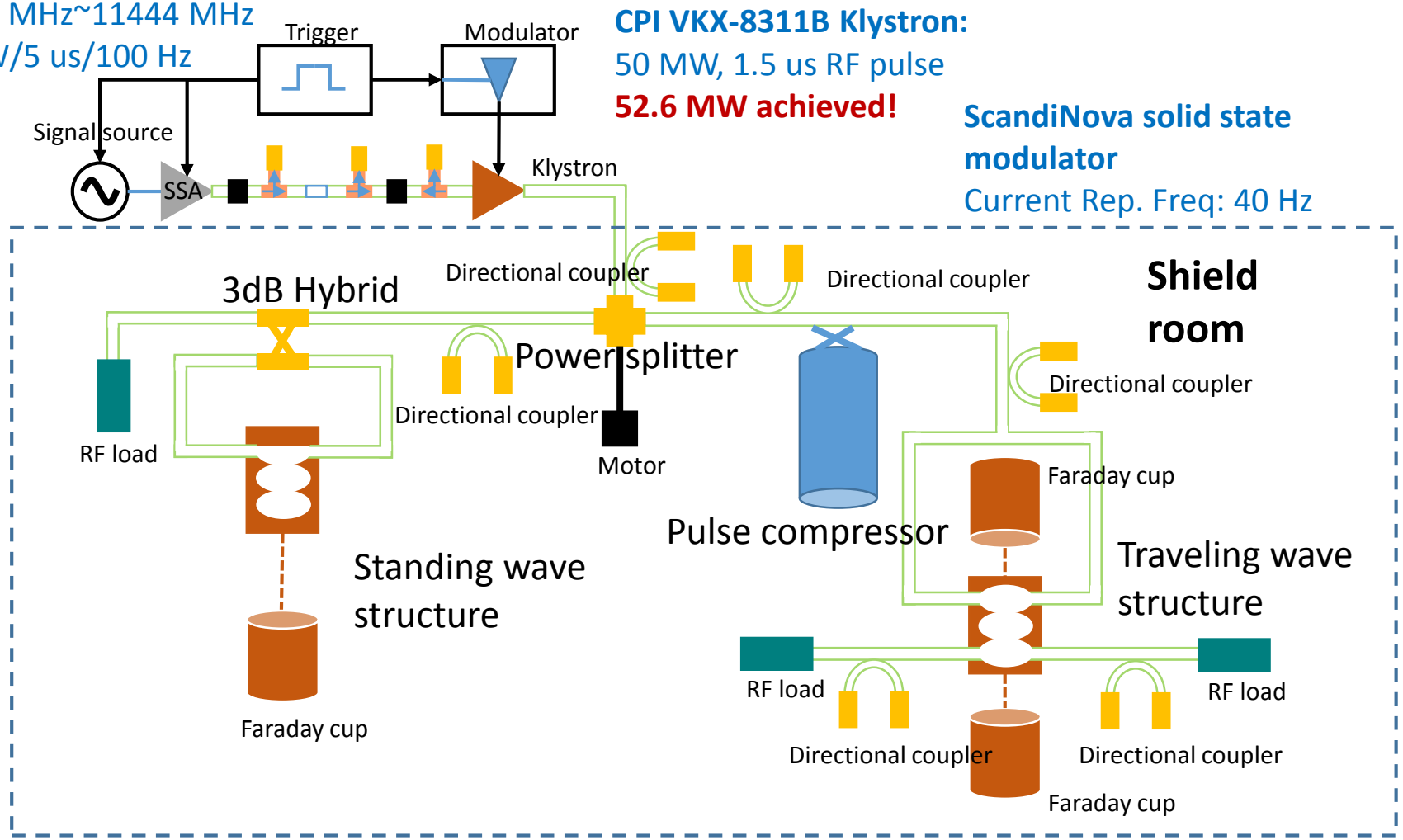


System diagram of TPoT-X

Signal Source and SSA
11404 MHz~11444 MHz
1.2 kW/5 us/100 Hz

CPI VKX-8311B Klystron:
50 MW, 1.5 us RF pulse
52.6 MW achieved!

ScandiNova solid state modulator
Current Rep. Freq: 40 Hz

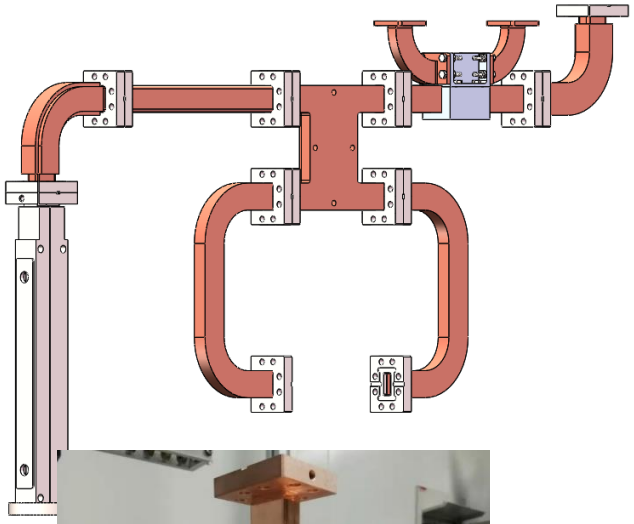


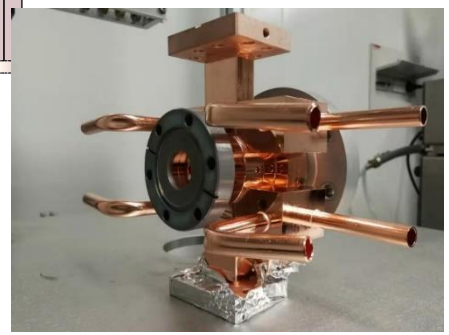
TPoT-X RF System w/ Power splitter

Courtesy of I. Syratchev and A. Grudiev

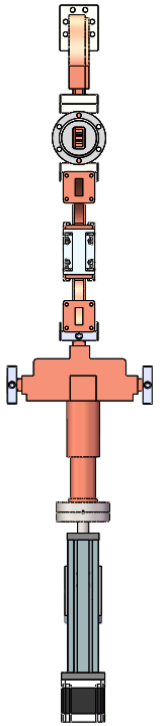
Left arm:

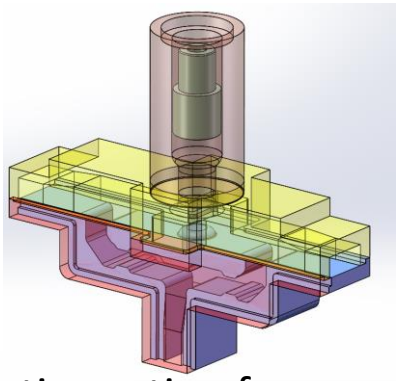
- No pulse compressor
- to test the **standing wave** structures





X-band RF gun



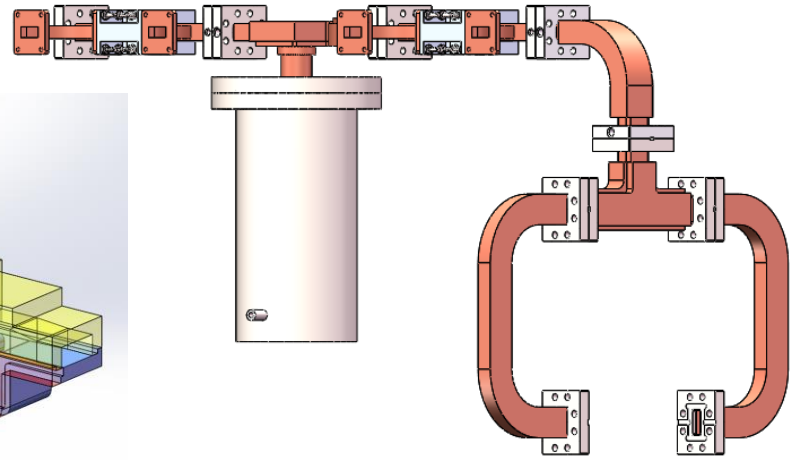


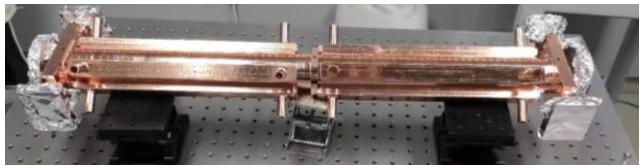
The power distribution ratio of the two branches can be changed by adjusting the position of the piston

Right arm:

- equipped with a pulse compressor

traveling wave structures, high power, short pulse





X-band 72 cell structure

Parameters and functions of TPot-X

- Tpot-X serves as an X-band high-power test stands
- Parameters:
  - Frequency: 11.424 GHz
  - Output of klystron: 50 MW, 1.5 us RF pulse

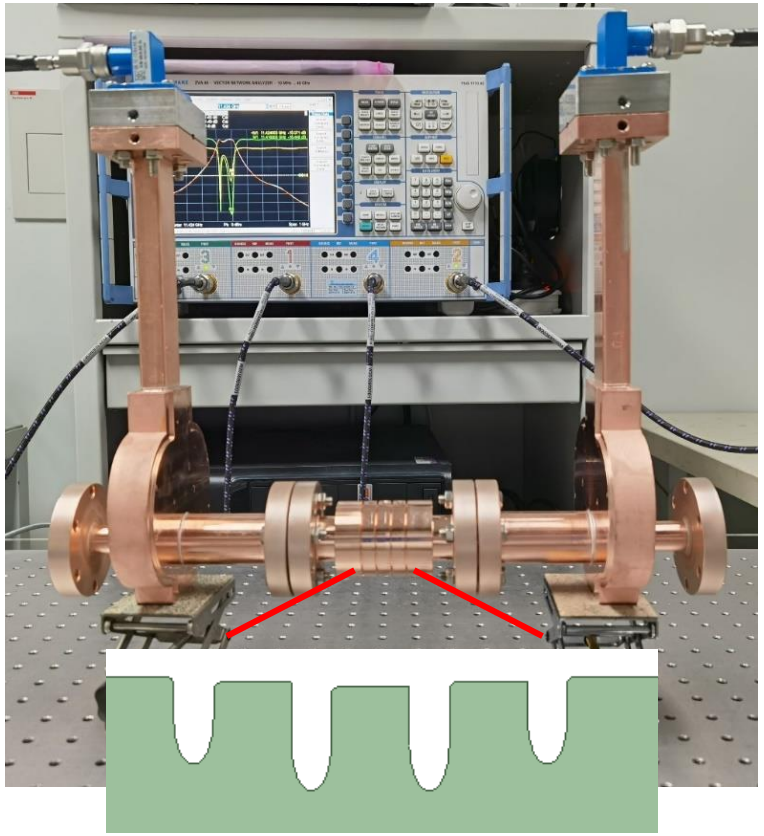
- Functions:
  - Test of high gradient structure
    - T24_THU#1, Single cell choke mode structures, single cell structure…
  - Structure conditioning
    - Accelerating structure for VIGAS, deflecting and accelerating structure for SXFEL…
  - Test of RF component
    - Pulse compressor, power splitter
  - Cathode imaging experiment with an X-band field emission gun

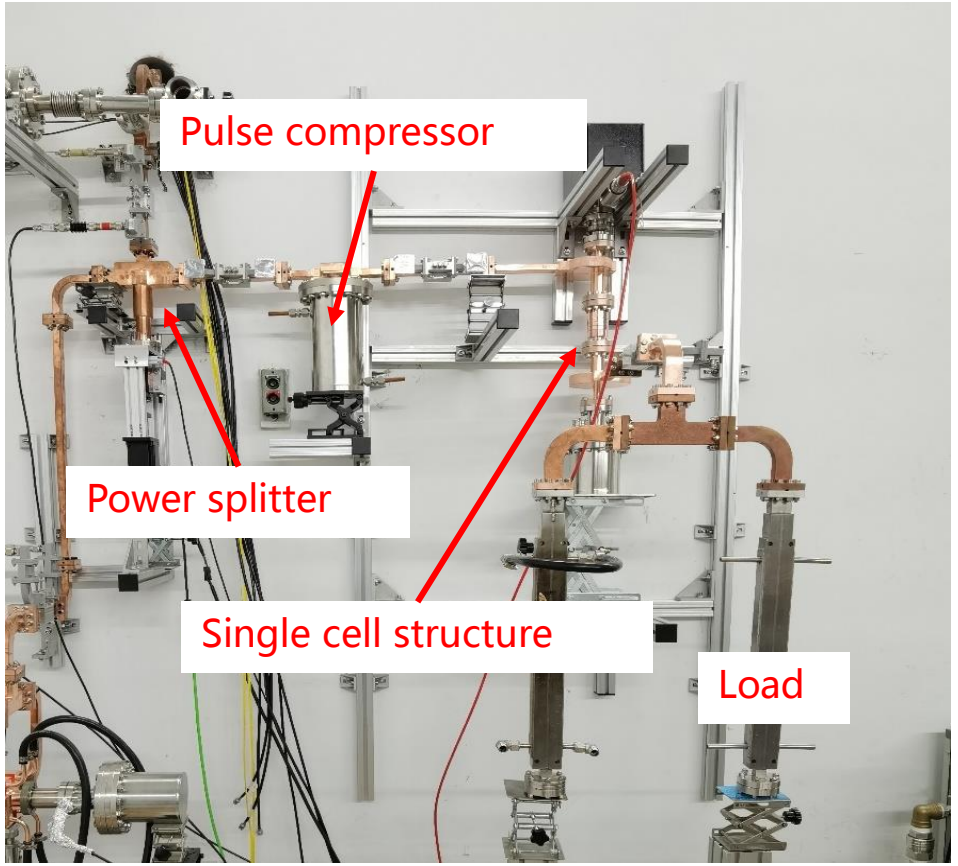
Recent activities at TPoT-X

- Single cell structure (finished 2021 Jan.)
- X-band deflecting structure (finished 2021 Mar.)
- X-band constant-impedance structure (finished 2021 July)
- X-band constant-gradient structure (finished 2021 Sept.)

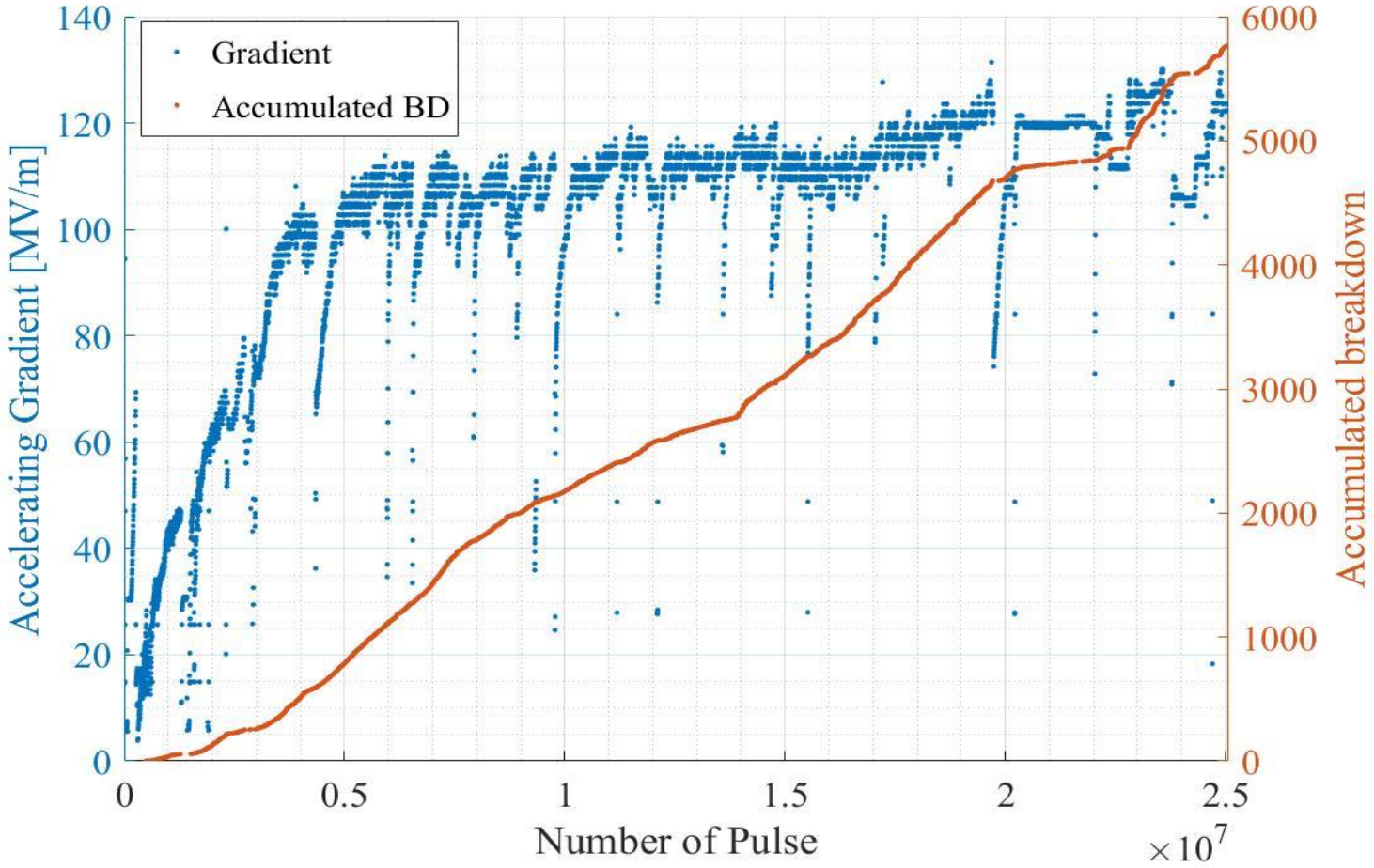
Single cell structure

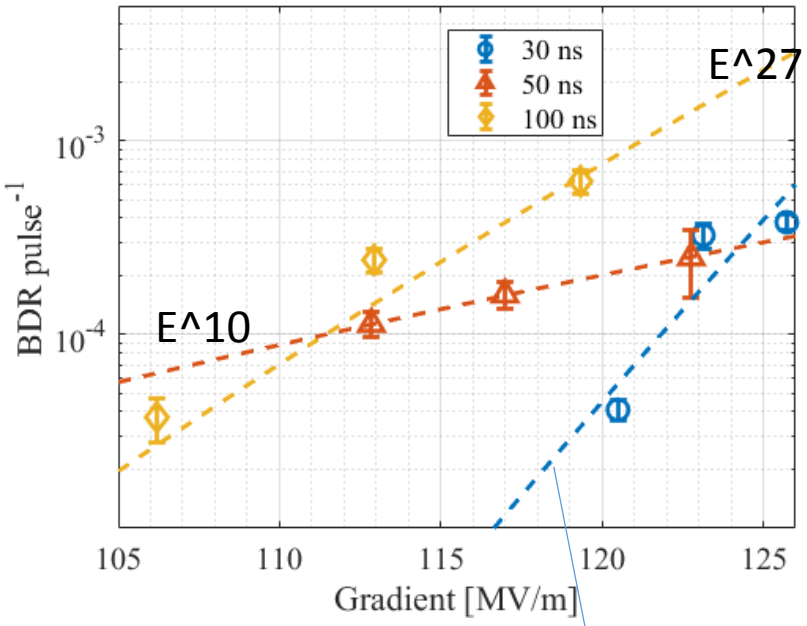
- Same design on 11.7GHz and 11.424GHz
- 11.7 version tested on AWA 400MW @ short pulse <10ns
- 11.424 version tested at TPoT





Single cell structure TW-A3.05T2.90 full history





E^27

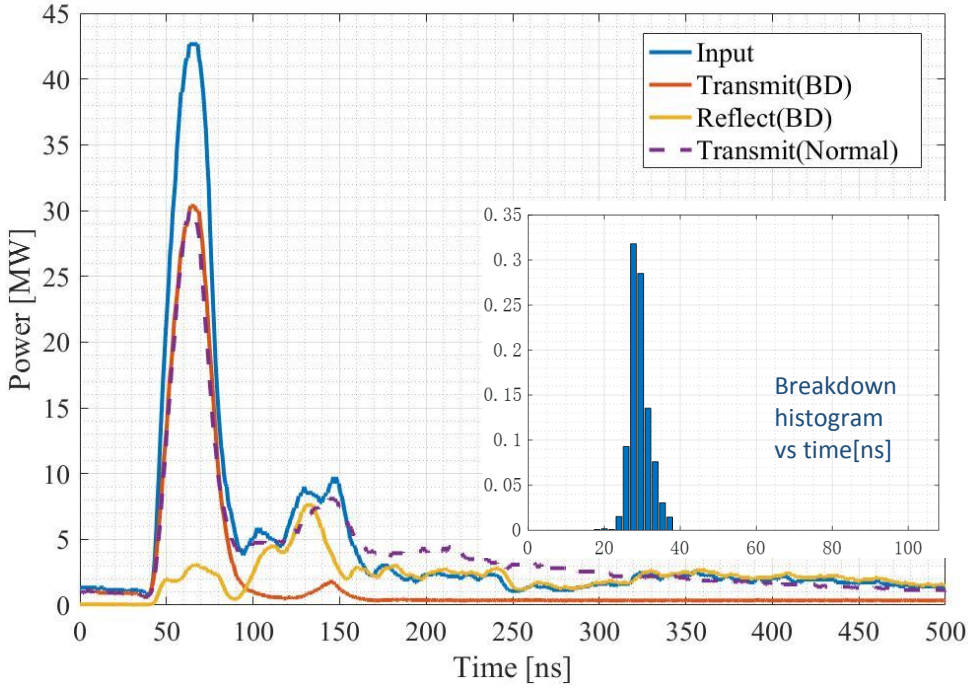
E^10

Small amount of pulses

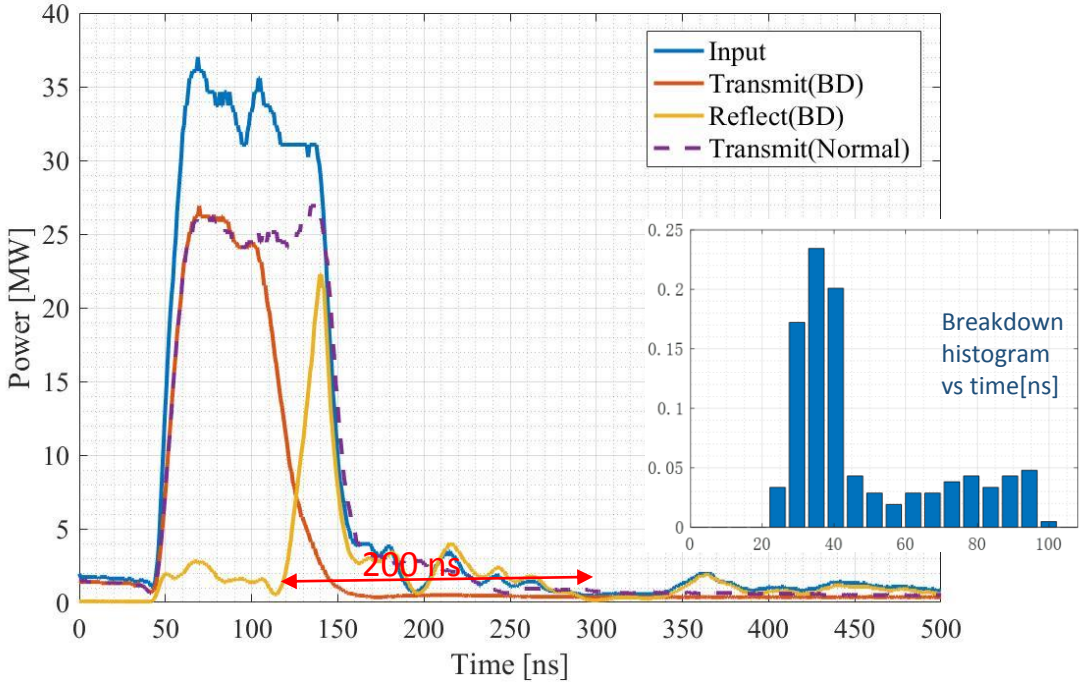
E^50

Single cell structure TW-A3.05T2.90

- Results of 30 ns and 100 ns are presented here.
- In 30-ns cases, breakdown is more likely to happen at the end of the pulse.
- In 100-ns cases, breakdown is more likely to happen at the middle of the pulse.



Breakdown pulse form with 30 ns input



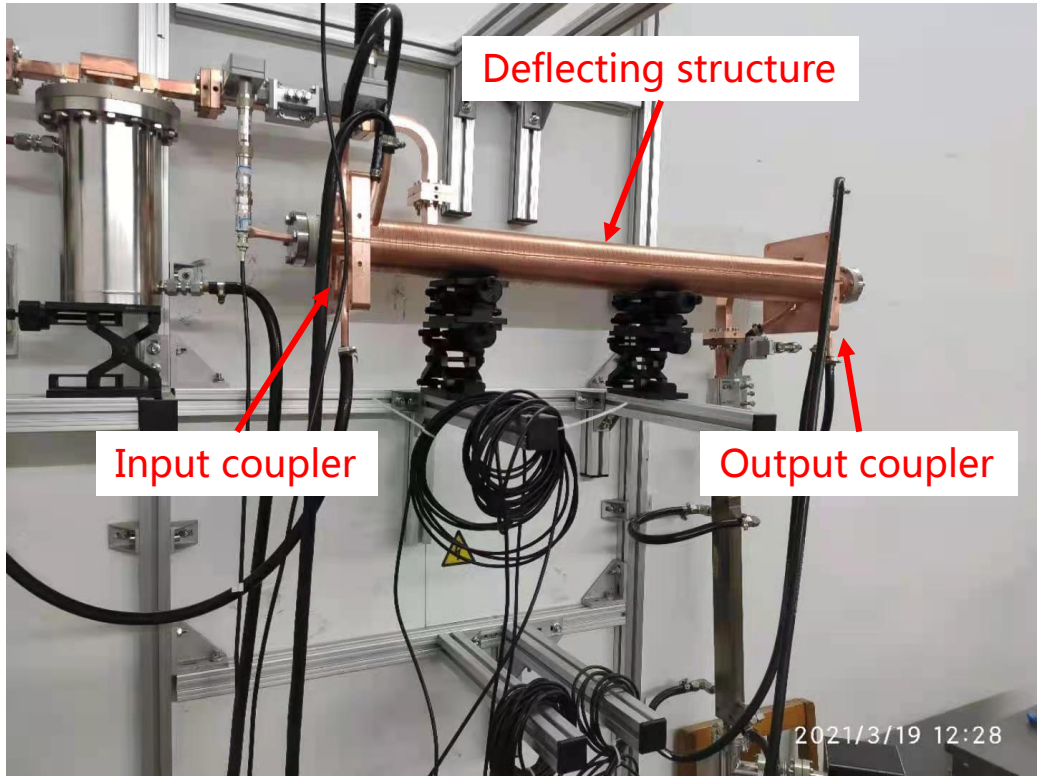
Breakdown pulse form with 100 ns input

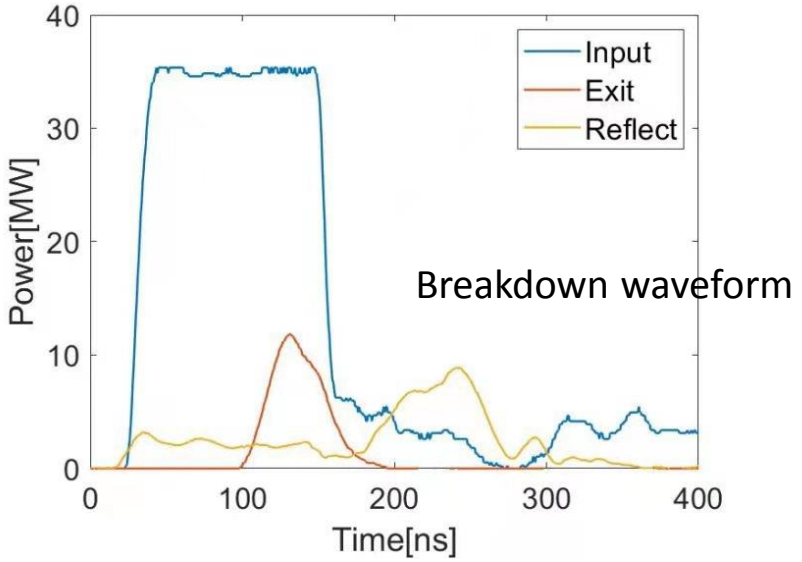
Recent activities at TPoT-X

- Single cell structure (finished 2021 Jan.)
- X-band deflecting structure (finished 2021 Mar.)
- X-band constant-impedance structure (finished 2021 July)
- X-band constant-gradient structure (2021 Sept.)

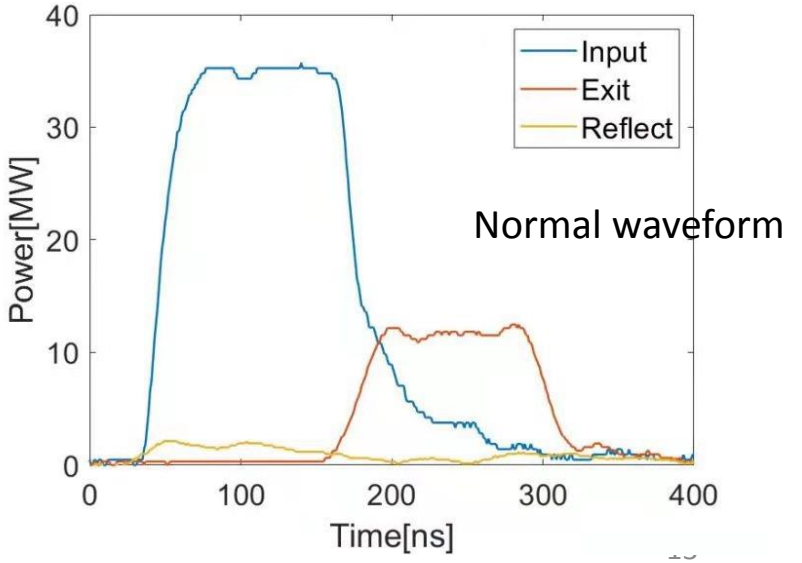
X band deflecting structure

- 1-m travelling wave deflecting structure for SXFEL.
- Developed at SINAP.
- **Milestone: First collaborated structure tested**





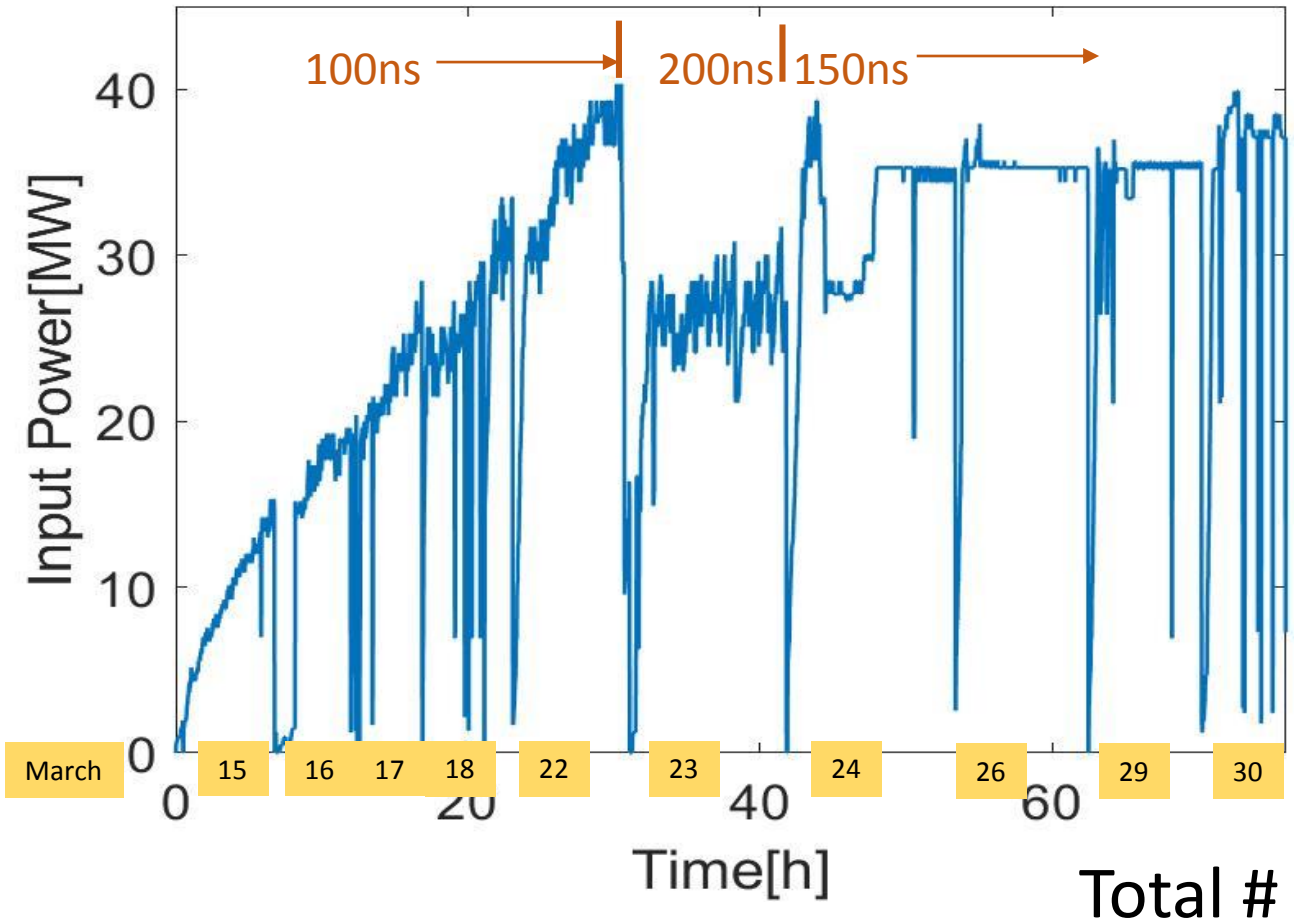
Breakdown waveform



Normal waveform

X band deflecting structure Full history

- The breakdown rate of 150 ns, 35 MW (nominal) was less than 1e-4



Total # pulse： 1e7

Recent activities at TPoT-X

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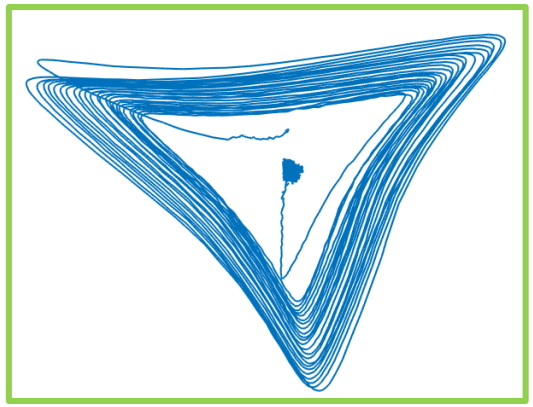
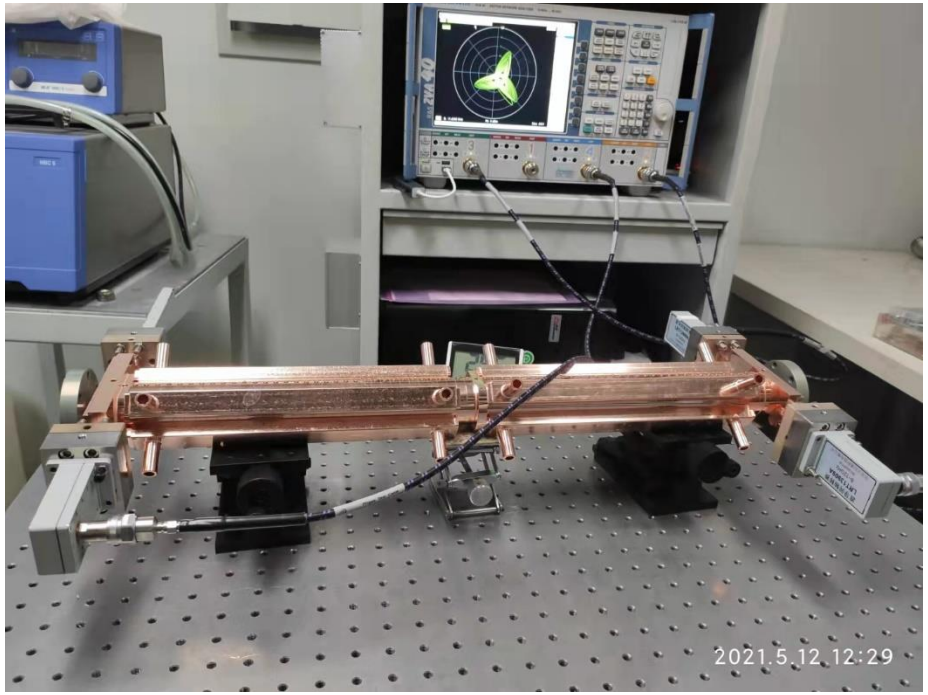
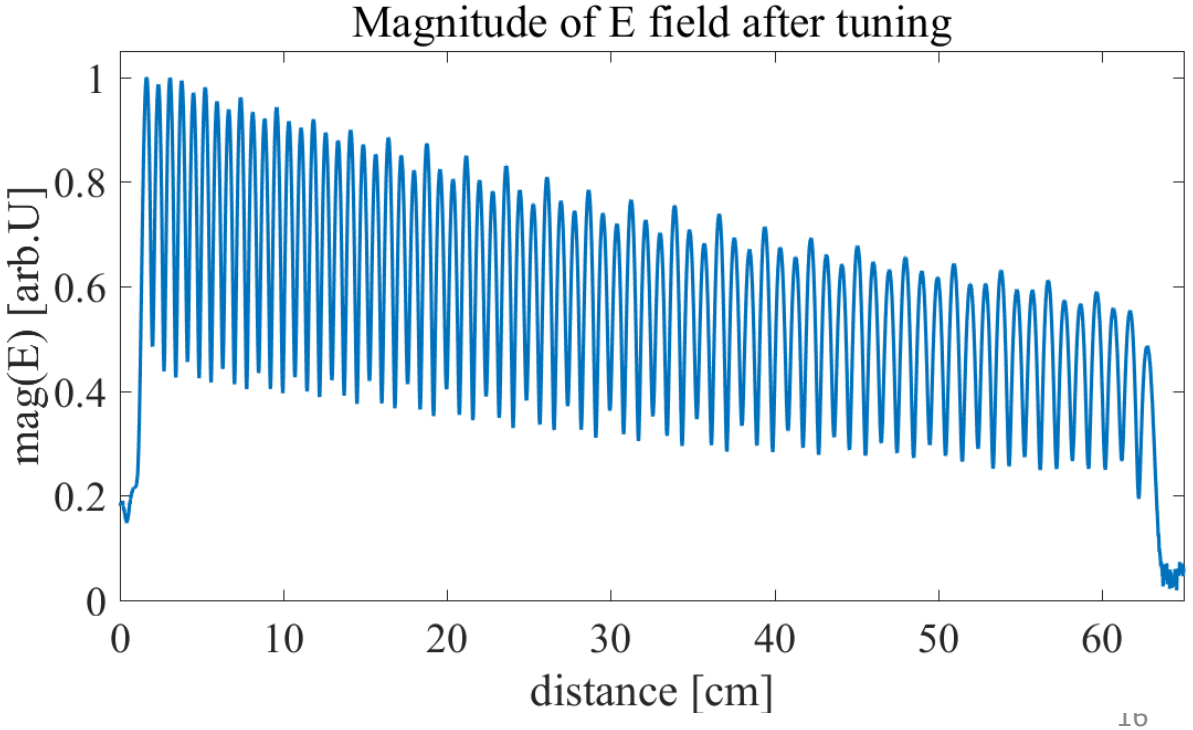
- X-band constant-impedance structure (finished 2021 July)
- X-band constant-gradient structure (2021 Sept.)

X-band Constant Impedance structure

- X-band Constant Impedance 72-cell travelling structure (XC72)
- Designed, fabricated and tested at Tsinghua.
- First prototype structure for VIGAS

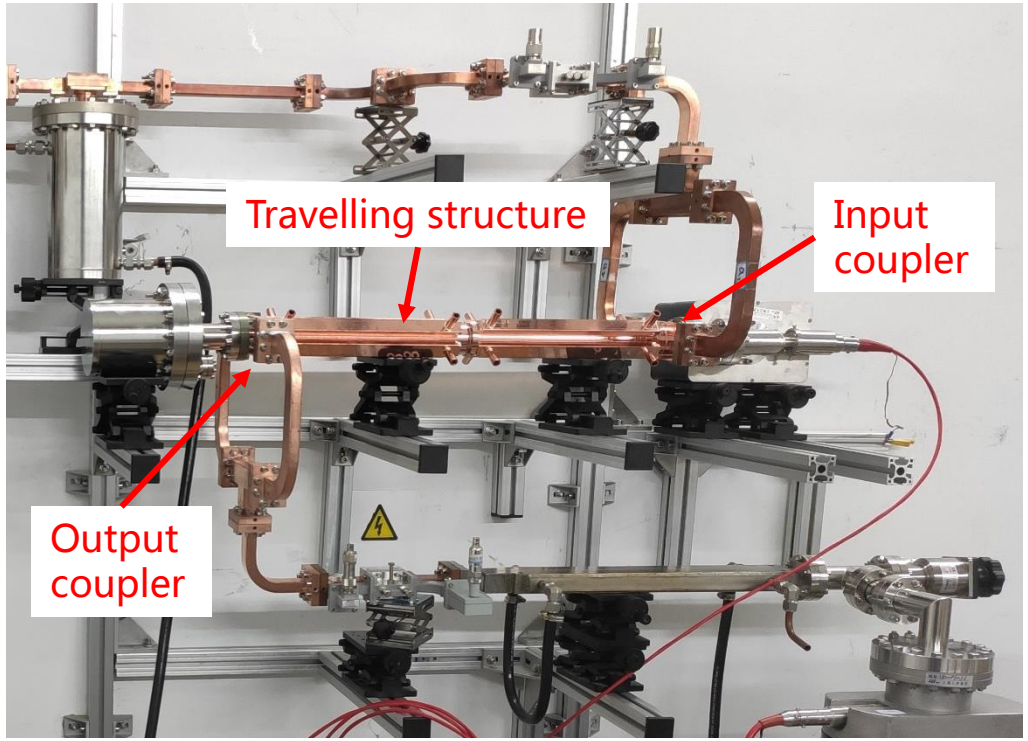


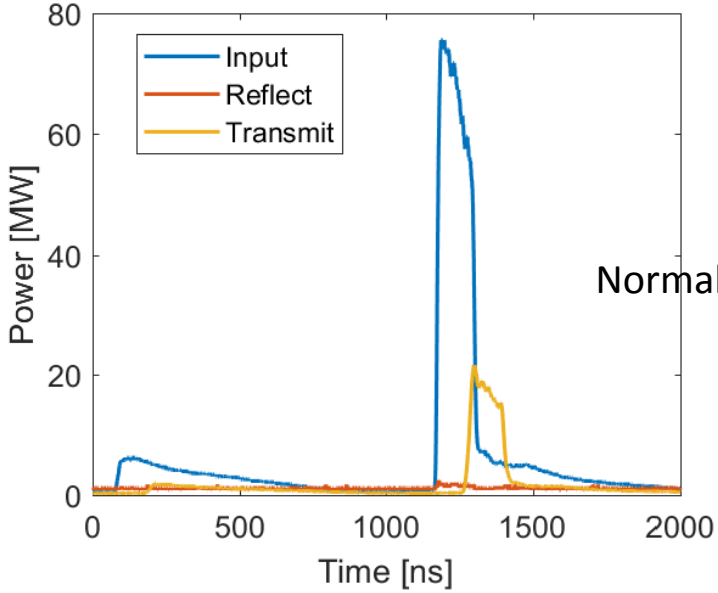




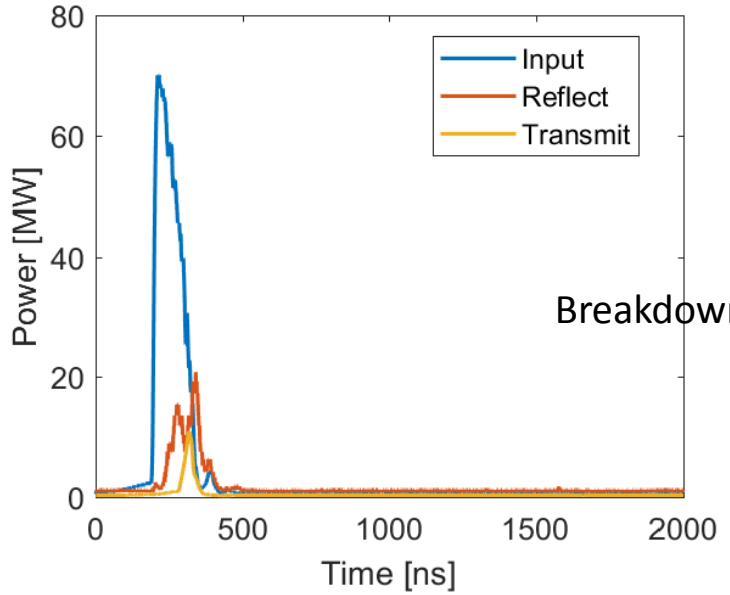
X-band linac

- The structure is high-power tested with the pulse compressor on.





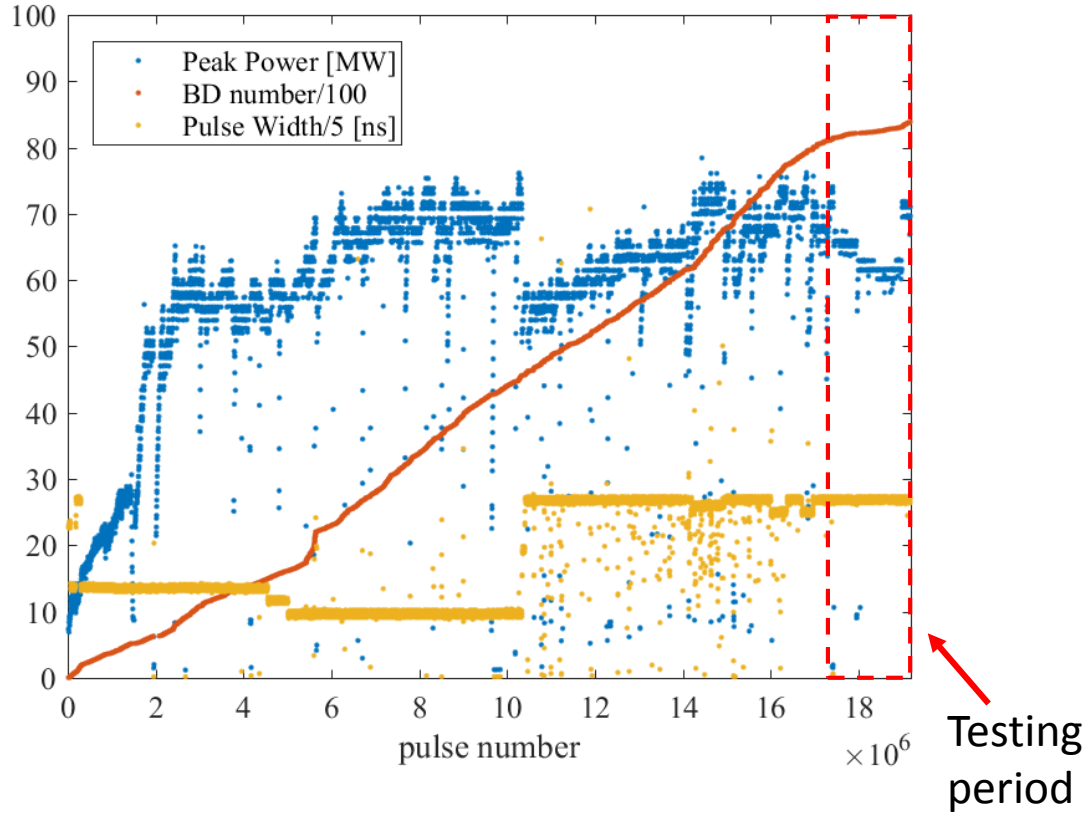
Normal waveform

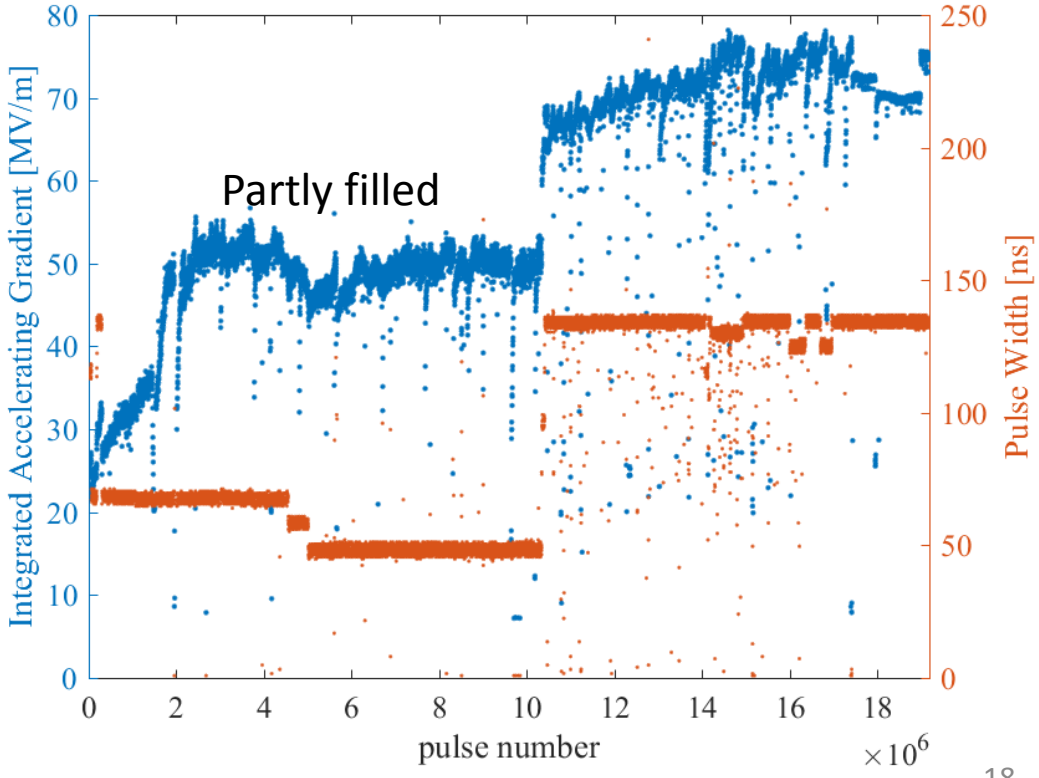


Breakdown waveform

X-band linac full history

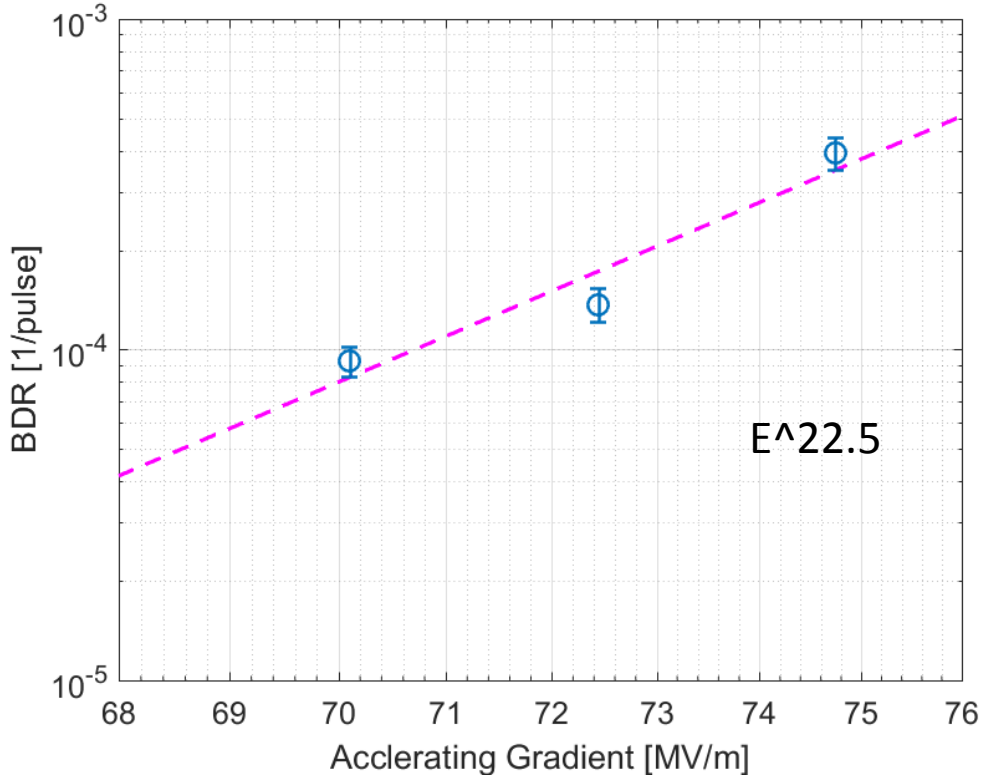
- The structure has been conditioned with 17 million pulses and tested with 2 million pulses.
- The target (80MV/m) was almost reached.

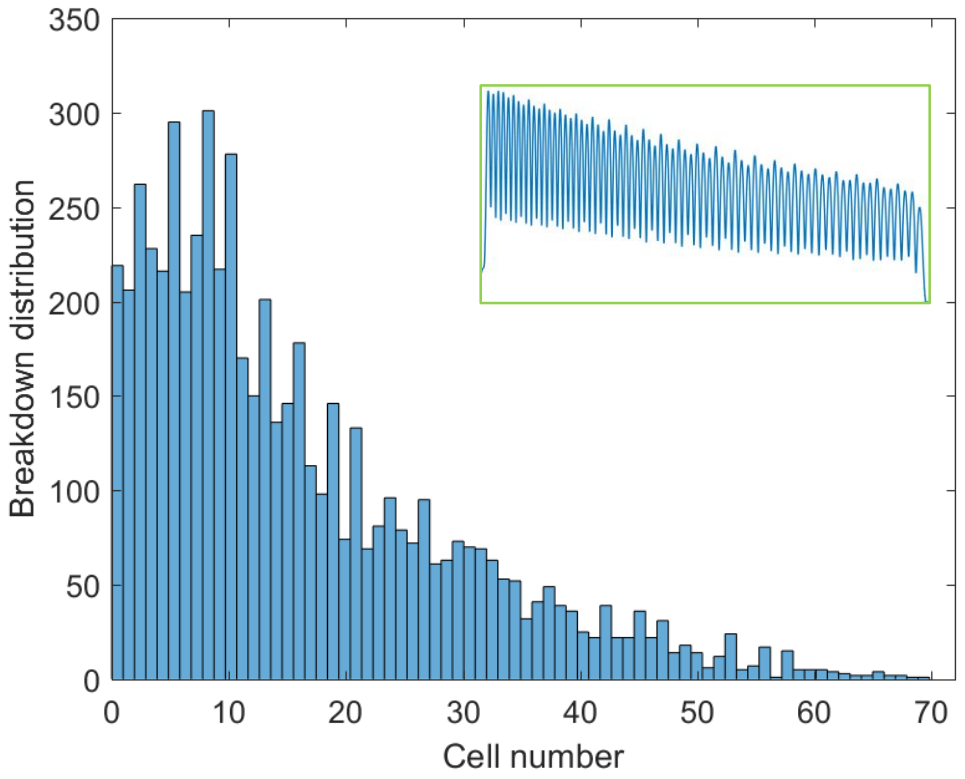




X-band linac conditioning history

- The breakdown rate versus accelerating gradient is close to the 30-power law
- The breakdown distribution is obtained from the input, transmit and reflect waveform





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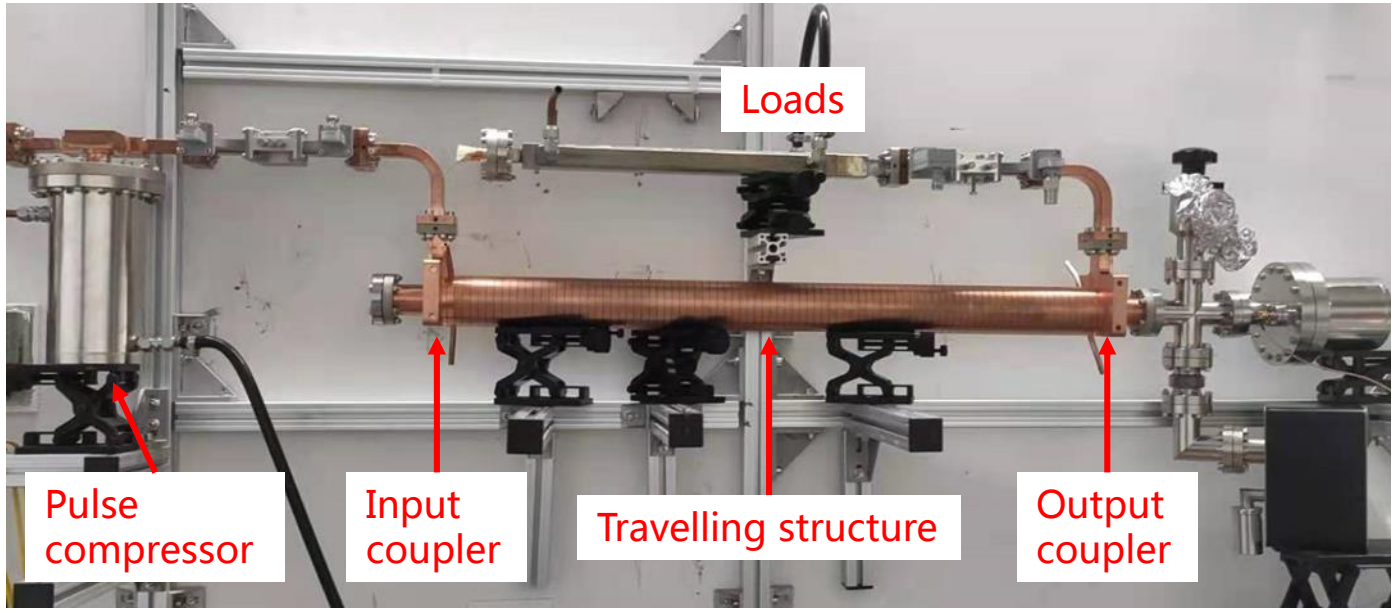
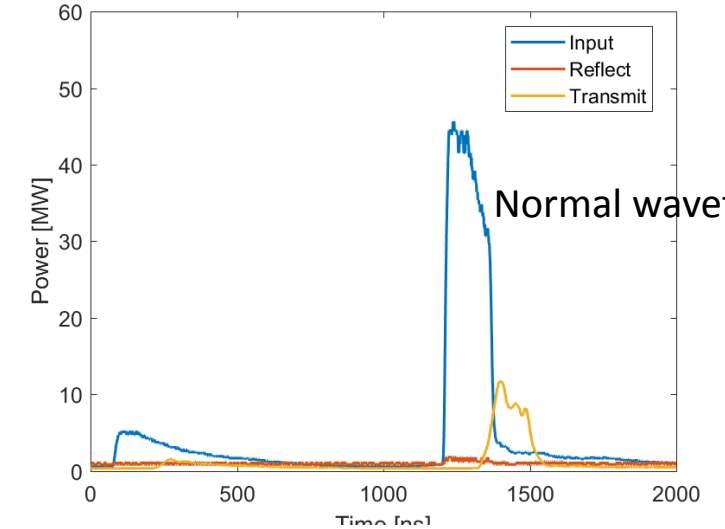
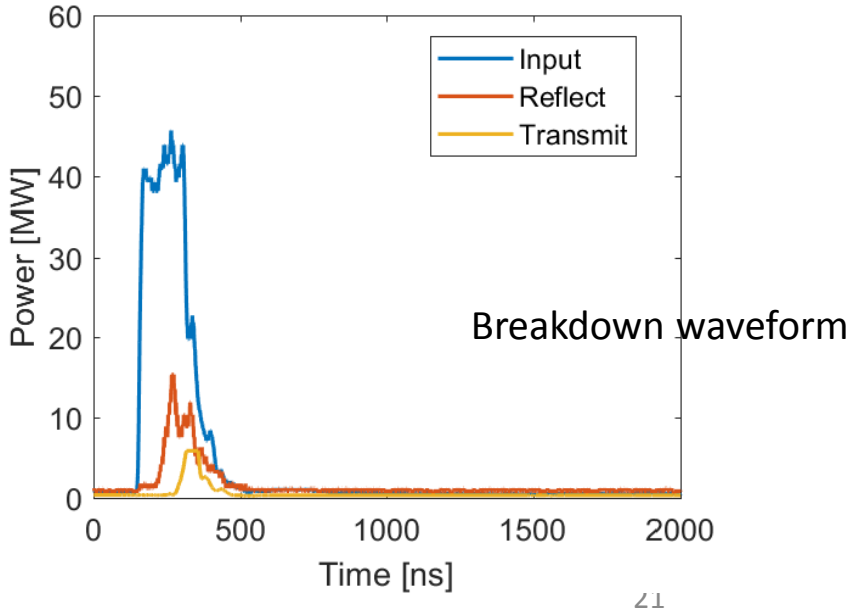
Constant gradient structure

- 1-m travelling wave constant gradient structure for SXFEL. Developed at SINAP.

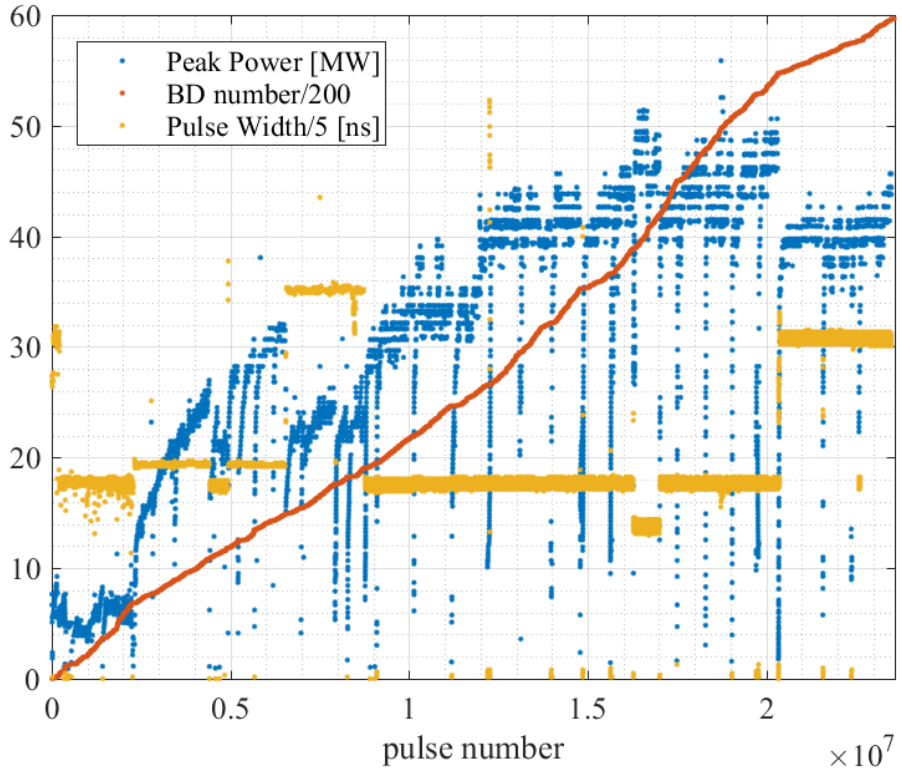


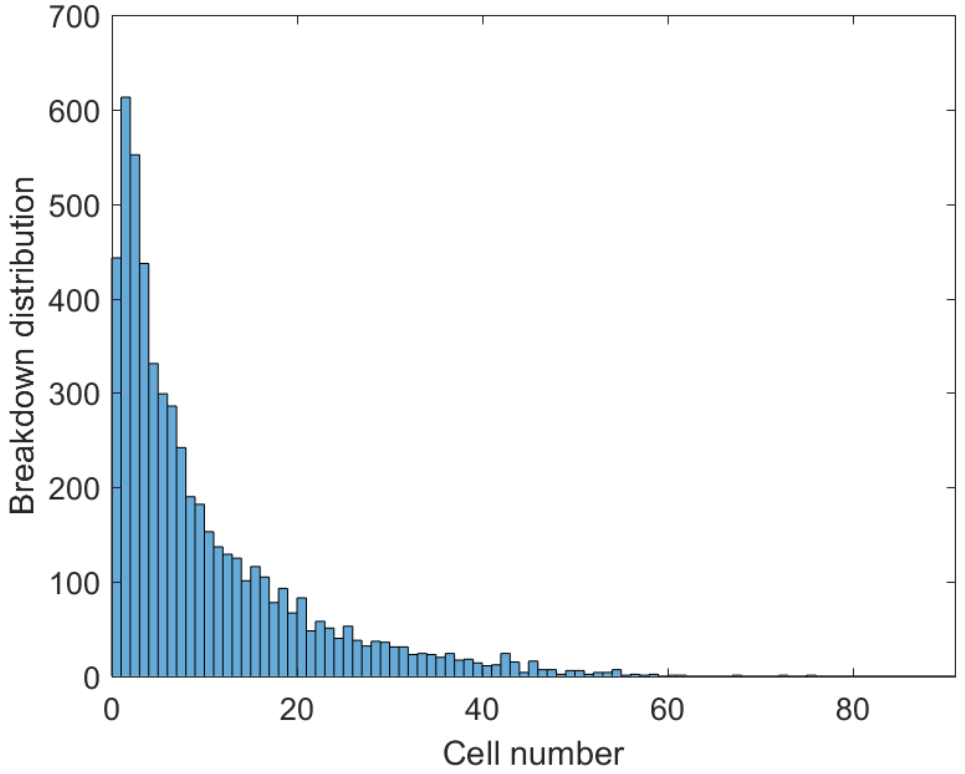




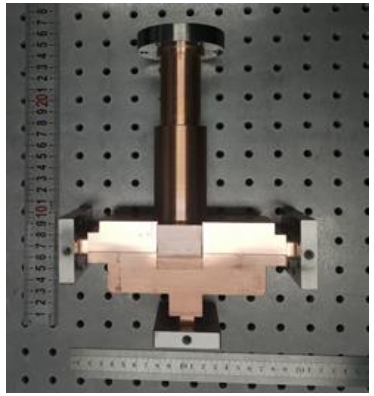
Constant gradient structure full history

- Still conditioning. ~23.5 million pulsed. The result (150ns, 46MW, ~60MV/m)
- It may be inferred from the breakdown distribution that the structure is not full conditioned

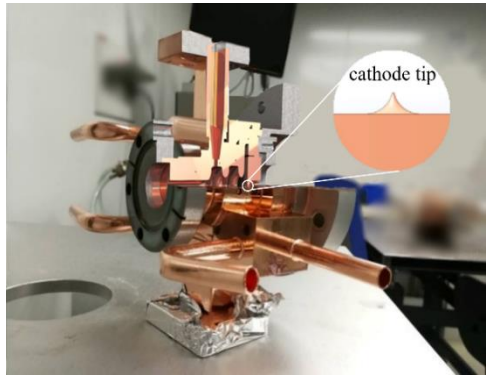




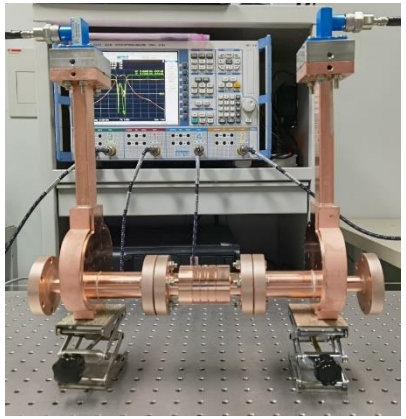
Timeline



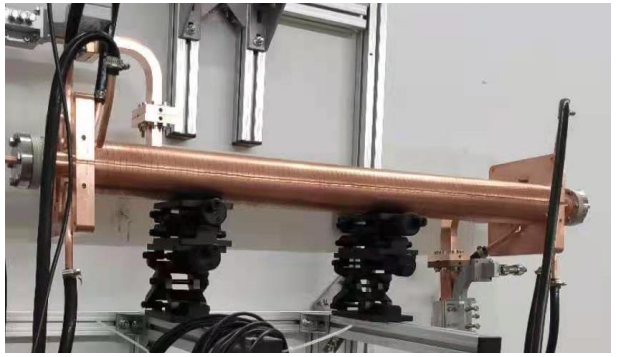
2020.09 Power splitter



2020.12 Field emission gun

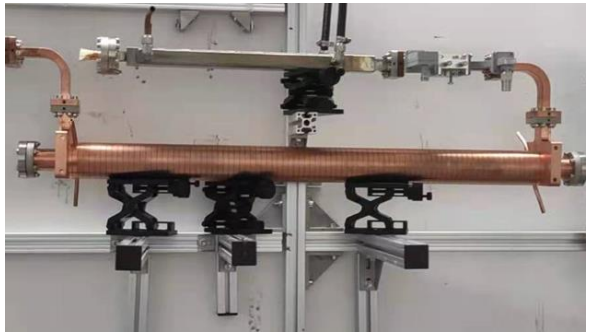


2021.01 Single cell structure



2021.05 Deflecting structure

2021.07 Accelerating structure



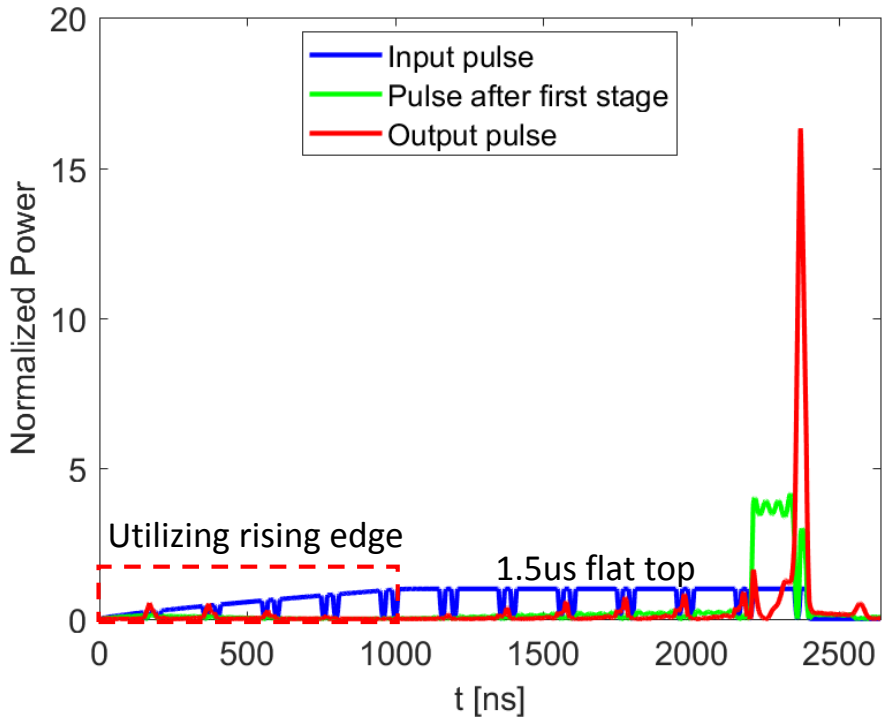
2021.09 Accelerating structure

Future plans—Test plans

Structures	Date
X-band deflecting structure. SINAP	May, 2021
XC72-Constant Impedance (VIGAS prototype)	July, 2021
X-constant gradient accl. SINAP	Sep, 2021, running
X-band RF gun	Running, since Jan 2021
Distributed-coupling structure	Oct, 2021
2-stage pulse compressor	Nov, 2021
T24-Half	Jan, 2022
XT72-constant gradient for 80MV/m (VIGAS prototype)	Mar, 2022

Two-stage pulse compressor

- Design peak power gain: 16
- Expected output power > 300 MW



Calculated pulse form

- The fabrication of RF components is finished
- Tuning and high-power test will be performed during Oct. and Nov.

Correction cavities

1st and 2nd stage storage cavity

Summary

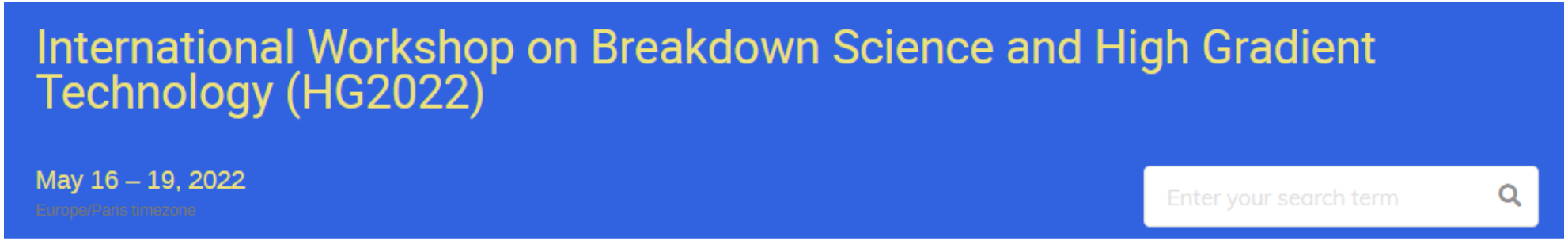
- VIGAS: compact 350MeV e-linac with X-band structures at 80MV/m.
  - Two more CPI 50MW klystrons by the end of 2022.
  - TPoT-X is very important experience for building the X-band beam line.
- Parameters of TPOT-X
  - 50MW, 1.5us, 40Hz from CPI VKX-8311B
  - Two arms w/ and w/o pulse compressor
  - ~200MW @100-200ns after pulse compressor, stable, for structure conditioning
  - >300MW @ 30ns-FWHM, also available for experimental structures,
- Run mode
  - 10h*(5-6)days / NOT for 24*7
  - 100~200h （~2e7 pulse） / month
  - 1-2month / structure
- Future plans
  - Two XT72's (630mm accelerating structure at 80MV/m) will be tested at TPoT in 2022.
  - Other time slots are open to different structures

Acknowledgements

- Many thanks to: Walter Wuensch, Igor Syratchev, Alexej Grudiev, Nuria Catalan Lasheras, Gerard Mcmonagle, Gerardo D’Auria, Toshiyasu Higo, Zhao Zhentang, Gu Qiang, Fang Wencheng, Wu Xiaowei … for their contribution and help

Announcement

- https://indico.cern.ch/event/1080222/



- We look forward to meeting again soon.

Thank you!