The progress of 300kW home-made fully solid-state transmitter for TPS
Outline

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Performance of Each RF Tower
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Introduction

The demand of 3rd RF plant for Taiwan Photon Source (TPS) storage ring (SR)
- For high beam current (500 mA)
- More Insertion Devices (IDs) in the coming future

A new 300kW RF system is planned to be installed in area SRF #4 of TPS
- 500MHz KEKB superconducting RF cavity module
- 500MHz 300kW transmitter
- RF feed lines
- LLRF

Fully solid-state power amplifier (SSPA) is chosen for 300 kW RF transmitter
- With the success of 80kW home-made Solid-state Power Amplifier (SSPA) prototype in 2019

Elements of 300kW fully solid-state transmitter
- Four 80 kW SSPA towers
- 3 WR1800 3dB hybrid couplers
- 3 80 kW water loads
- WR1800 waveguides piping

Construction schedule for 3rd RF system
- Complete the 300kW SSPA system within 2 year (2020-2021) and
- Integration with LLRF and SRF cavity module in 2022
500MHz 300 kW SSPA System Design

Frequency: 499.65 MHz
Power rating: ≥ 300 kW
Bandwidth: ≥ +/−1 MHz
Power gain: ≥ 75 dB
Side band noise: ≤ 65 dBc
Harmonic: ≤ 40dBc
Single 80kW SSPA Tower design

Frequency: 499.65 MHz
Power rating: ≥ 80 kW
Bandwidth: ≥ +/−1 MHz
Power gain: ≥ 80 dB
Side band noise: ≤ 65 dBc
Harmonic: ≤ 40 dBc

Elements:
- 100 W pre-amplifier x4
- 600 W drive amplifiers x6
- 880 W amplifiers x110
- 4-way divider/combiner (400 W) x2
- 6-way combiner (3.6 kW) x1
- 10-way divider (3.6 kW) x1
- 11-way divider (300 W) x10
- 11-way combiner (8.5 kW) x10
- 10-way combiner (80 kW) x1

For better redundancy in pre-amplifier
100W x 4

1-way N to N divider

6-way 7/16" to 1 5/8" coaxial combiner

Add isolator to improve power balance

Add isolator to improve power balance

RG213 N-type
Mini-circuit
ZGBDC30-372HP+

6 1/8" Spinner

Add isolator to improve power balance

80kW
10-way 3-1/8" to 6-1/8" Traveling wave coaxial combiner
Power performance of one 80kW SSPA tower

Tower #1 and #2 are accomplished in 2020

- AC-RF efficiency: 54%@80kW&48V
Quality Performance of one 80kW SSPA tower

Tower #1 and #2 are accomplished in 2020

- Side band noise = -66.7 dBC @ 60Hz
- 2\textsuperscript{nd} Harmonic = -42.86 dBC
- 3\textsuperscript{rd} Harmonic = -47.51 dBC
- Phase noise = -66.23 dBc @ 60Hz
  - -71.77 dBc @ 265Hz
- Group delay = 131 ns
Power combination of 2 SSPA towers

DC voltage range: 44, 46 and 48V

Opt. Eff. @ 44V=54.87%@142kW
Opt. Eff. @ 46V=54.76%@152kW
Opt. Eff. @ 48V=53.67%@160kW
Quality performance of 2 SSPA towers combine

Meet the specification

**Sideband noise**
- $-70.83\text{dB} @ 258\text{Hz}$

**Phase noise**
- $-70.92\text{dBc}@60\text{Hz}$
- $-70.58\text{dBc}@258\text{Hz}$

**Harmonics**
- $-55.15\text{dBc} @ 2^{\text{nd}} \text{harmonic}$
- $-69.48\text{dBc} @ 3^{\text{rd}} \text{harmonic}$
Long-term reliability of 2 tower combine

Start from 2021/4/13: interrupted by interlock and repeat test twice (1st is AC copper wire burn, 2nd is water flow sensor wrong action)

3rd Start at 2021/05/01: 2021/05/01 21:00 ~ 05/16 9:00 14day+12hr 150kW CW test OK

Total combined test period: 11days18hr+2days18.5hr+14days12hr = 29days0.5hr

Test condition: to RF load no reflection,

Results: No SSPA module fault or power degradation
Future work

Finish the other 2 SSPA towers in 2021

Apply RF power test for last 2 SSPA towers separately

Accomplish 4 SSPA towers power combination for 300 kW