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Broadband L-Band Traveling Wave Tubes for Navigation Satellites

L2.1-2 8th IVEW 2022

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Overview

L-Band TWTs for navigation satellites

- ESA Horizon 2020 project

Design challenge: Broadband, high-power L-Band TWT

Current status of development

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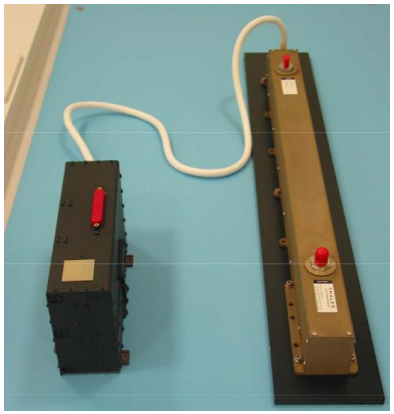
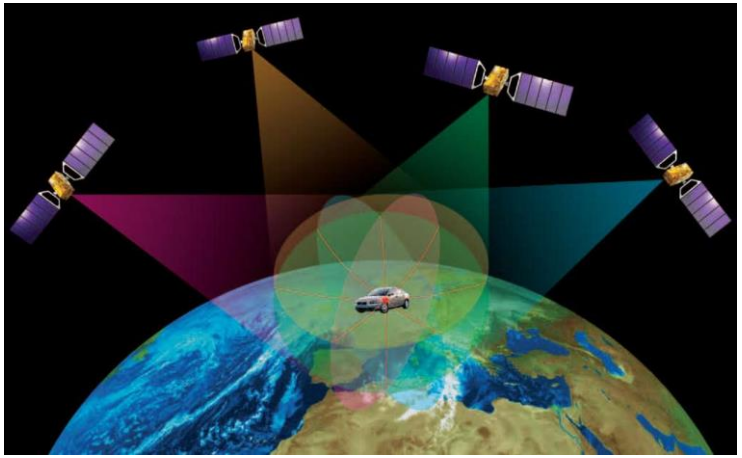
TWT vs. SSPA for Navigation Satellites



Thales GIOVE-A
80W L-Band TWT



Honeywell ARTES4
15W GaN SSPA
source: www.artes.esa.int

L-Band power amplifiers: TWTs or SSPAs

- TWT: Robust versus temperature, radiation, interference
- SSPA: Flexible (array antennas), light-weight
- Power / efficiency no longer a big differentiator (at least in L-Band)

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ESA: Horizon 2020 Next-Generation Satellite Navigation

Satellite navigation frequencies:

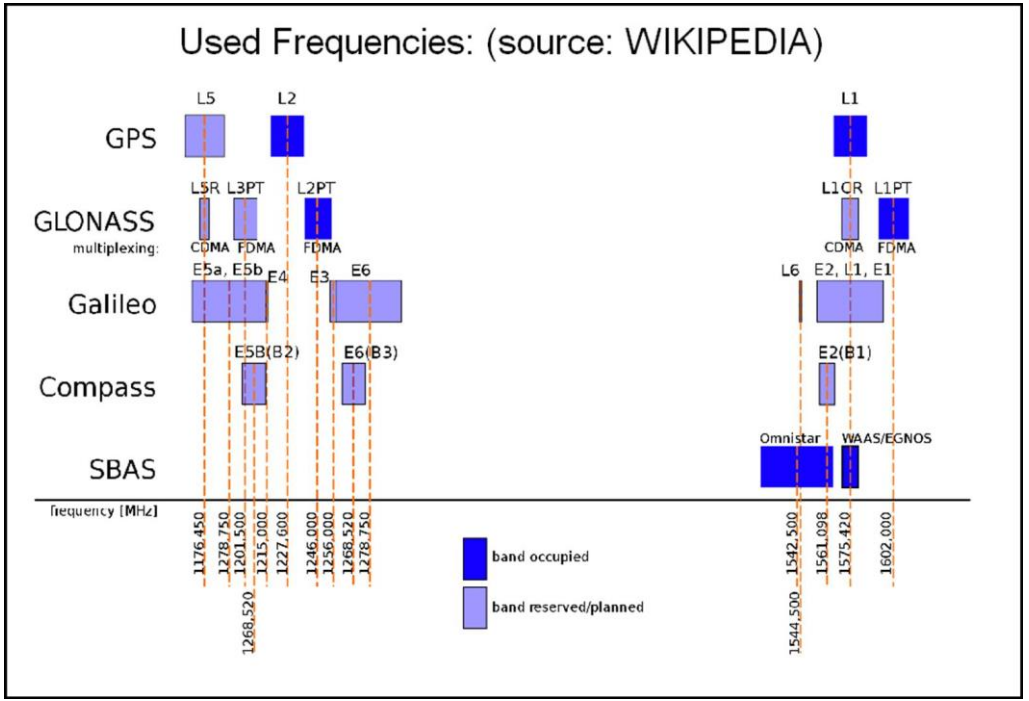
- Lower band: ~1.1GHz to ~1.3GHz
- Upper band: ~1.55GHz to ~1.6GHz

H2020 sub-project: Linearized TWT Amplifier (L-TWTA) for the entire frequency band from 1.145GHz to 1.6GHz

- High power: 200W-230W due to multiple simultaneous signals
- Power-flexible operation desired

Reduction of TWT number by a factor of 3

- 1 + 1 spare per satellite



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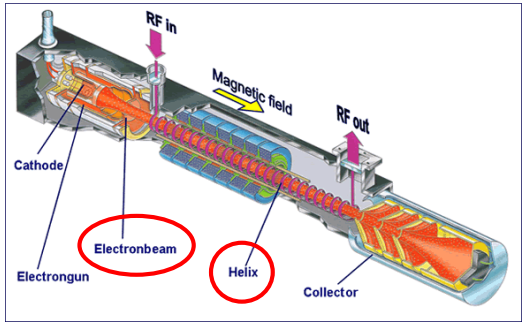
„Ideal“ TWT delay line: phase velocity profile



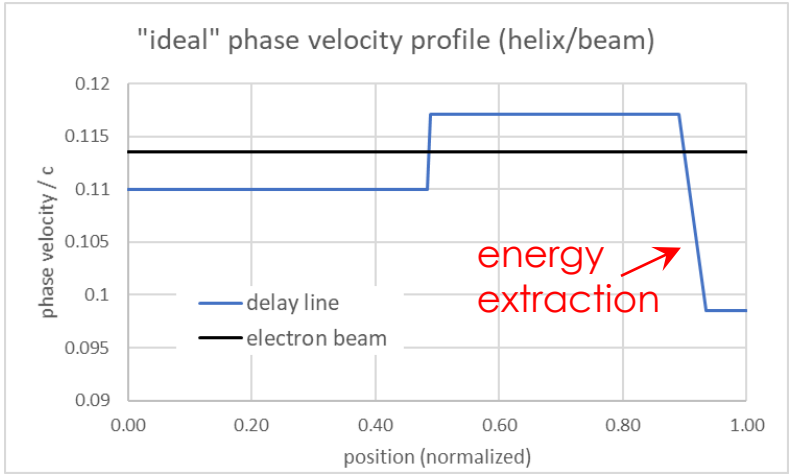
beam / wave:

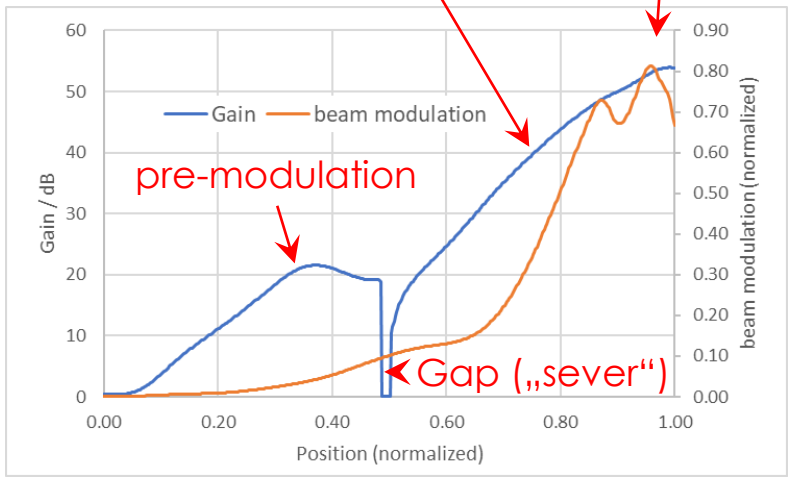
equal phase velocity (synchronous)

=

strong interaction

Result:
- high output power
- good linearity





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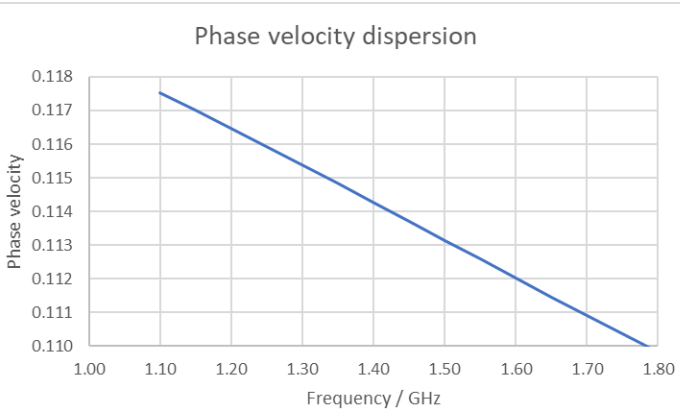
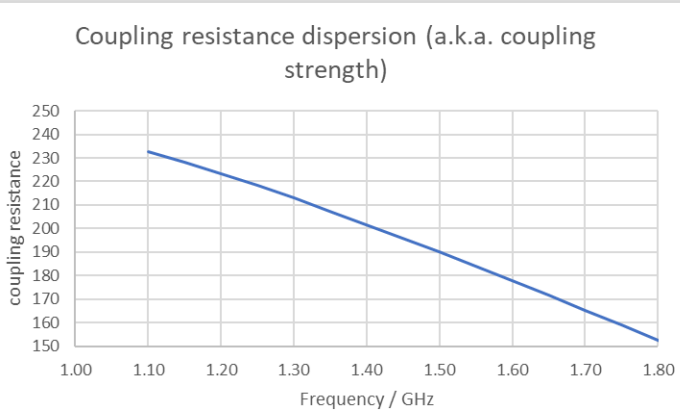
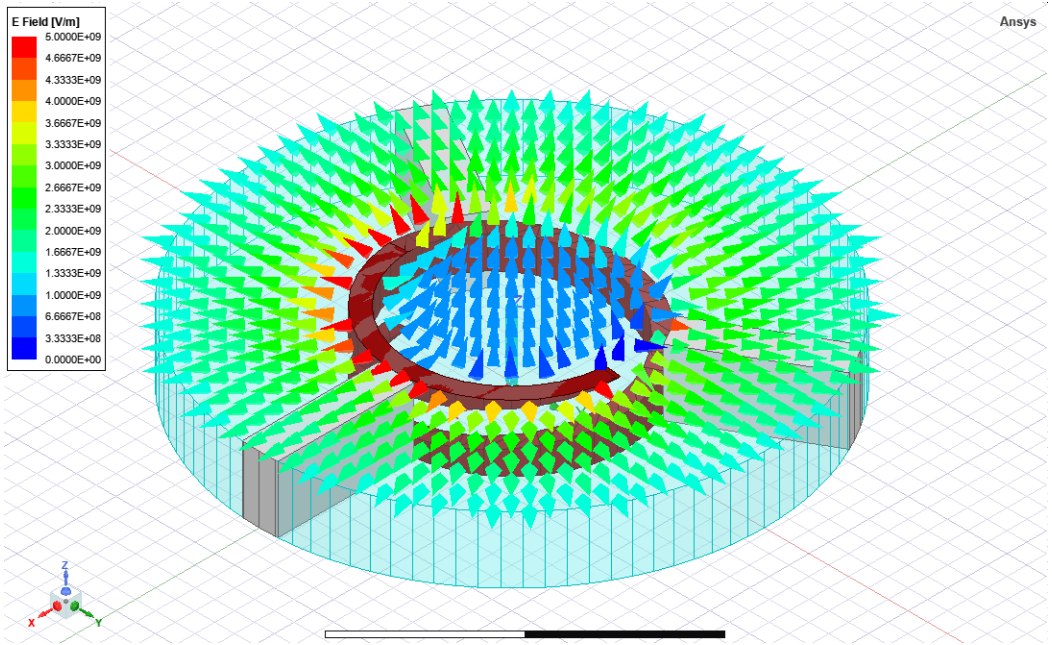
Delay Line Dispersion







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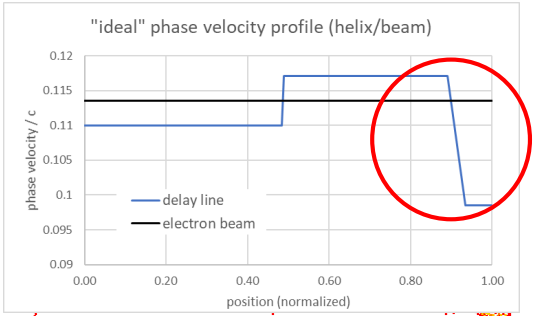
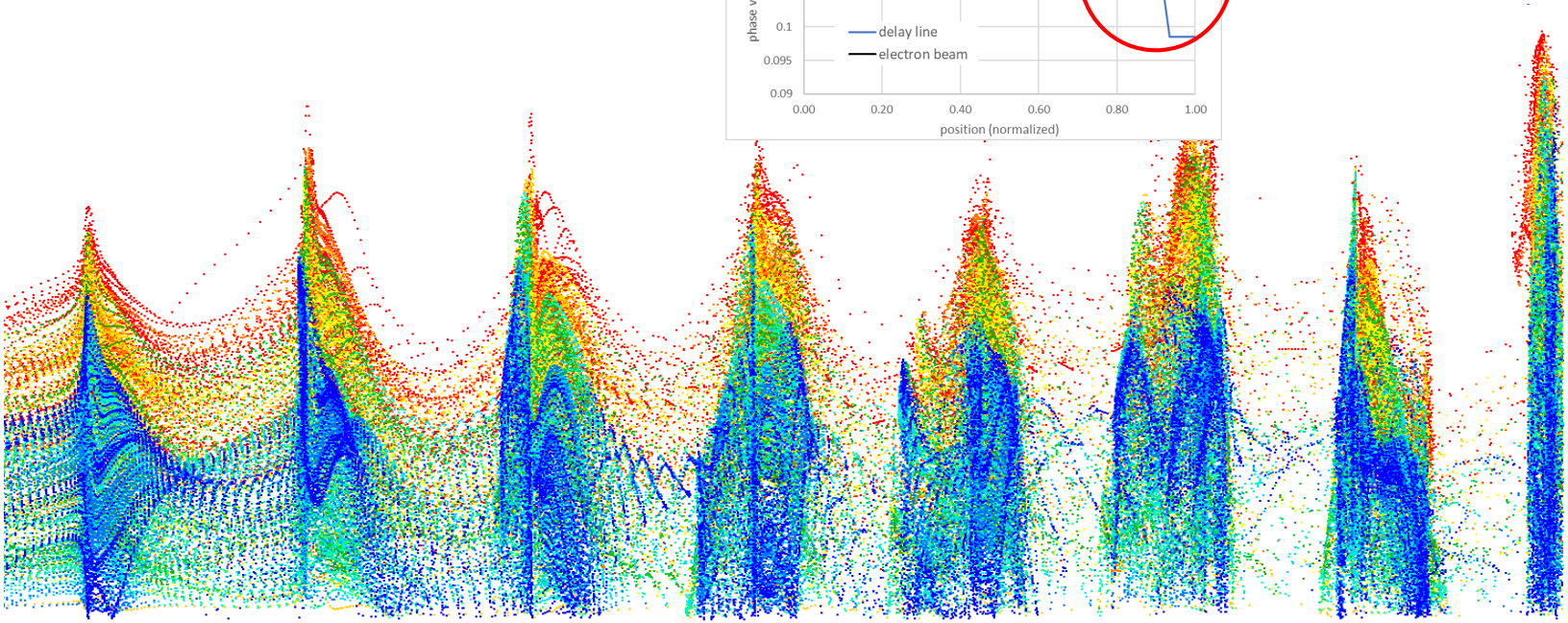
Harmonics

- Nonlinear bunching near output
- Strong harmonic content





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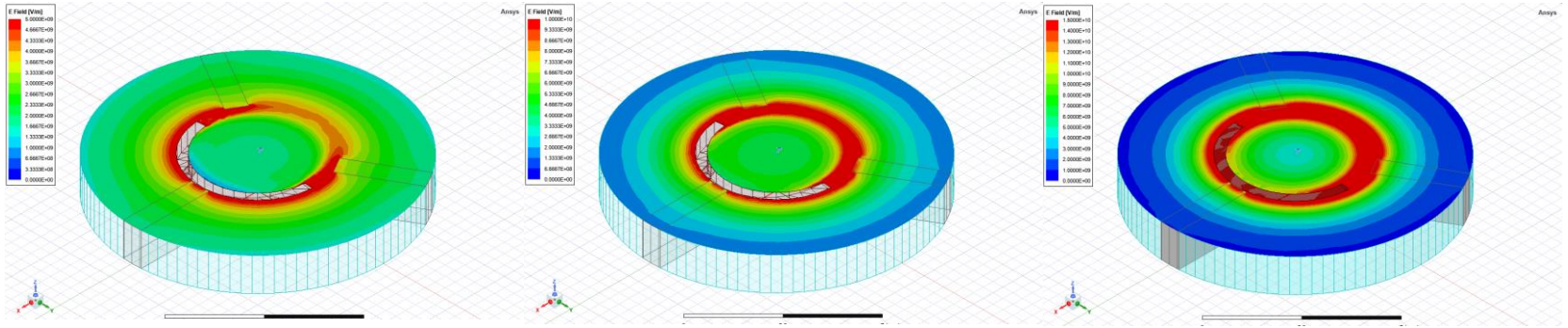
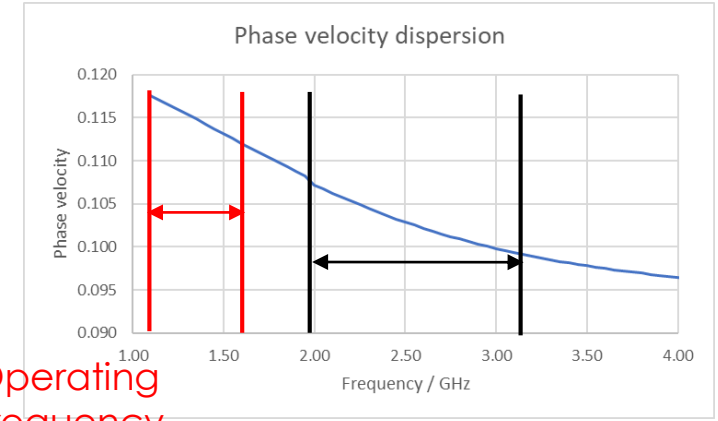
Harmonics (not enough dispersion)



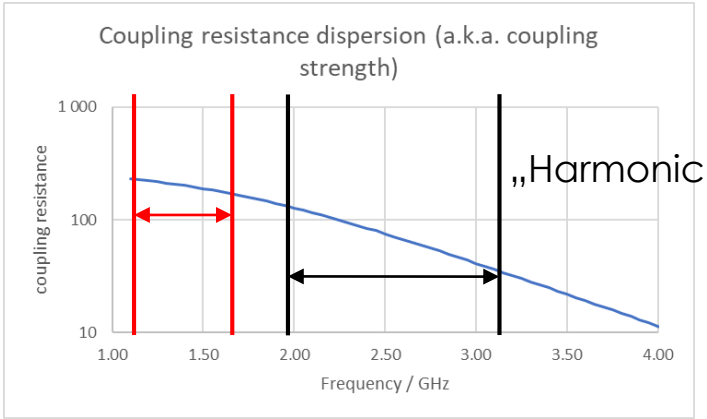
E-Field: 1.2GHz

E-Field: 2.4GHz

E-Field: 3.6GHz



Operating frequency



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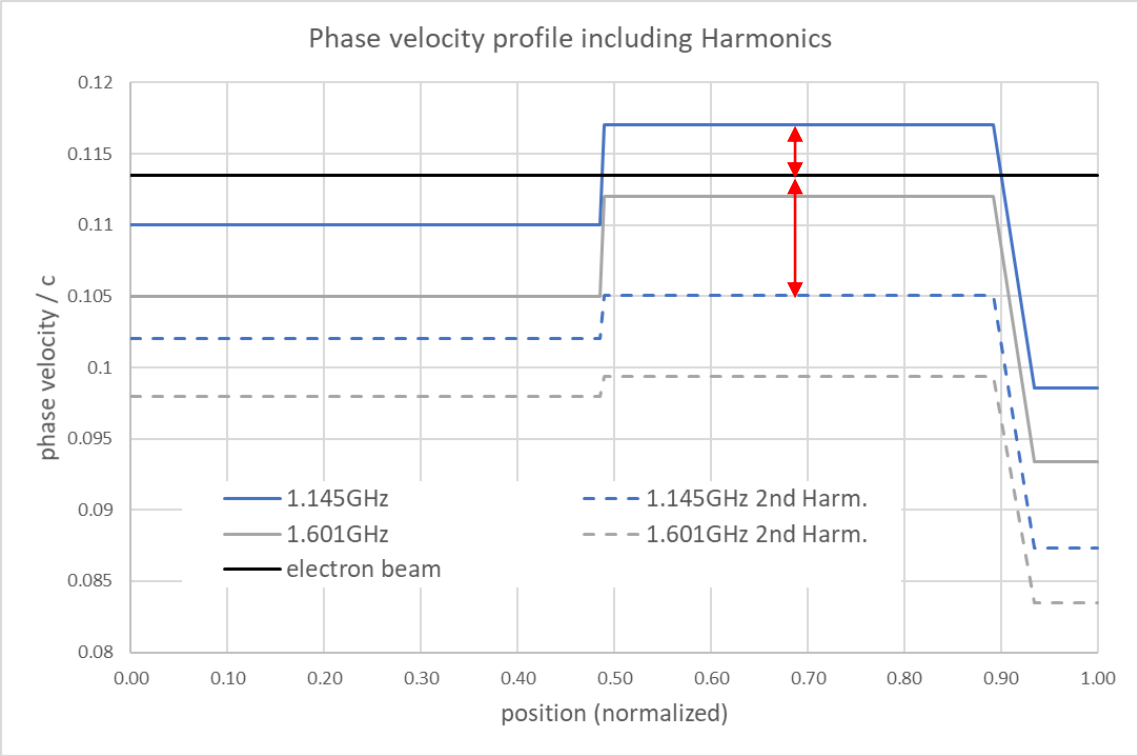
Phase velocity trade-off

Phase velocity high:

- Good performance in upper band
- Very strong harmonics + low output power in lower band

Phase velocity low:

- Low output power and strong nonlin. phase shift in upper band
- Good performance in lower band



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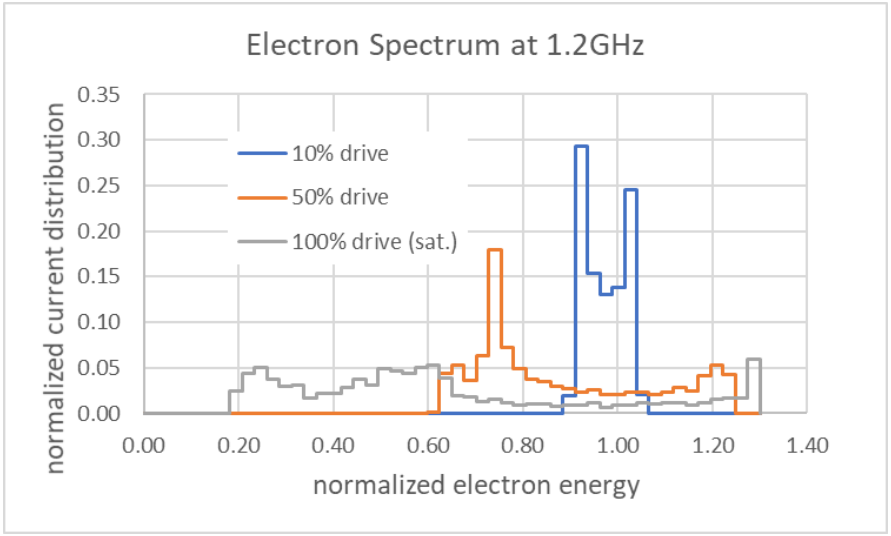
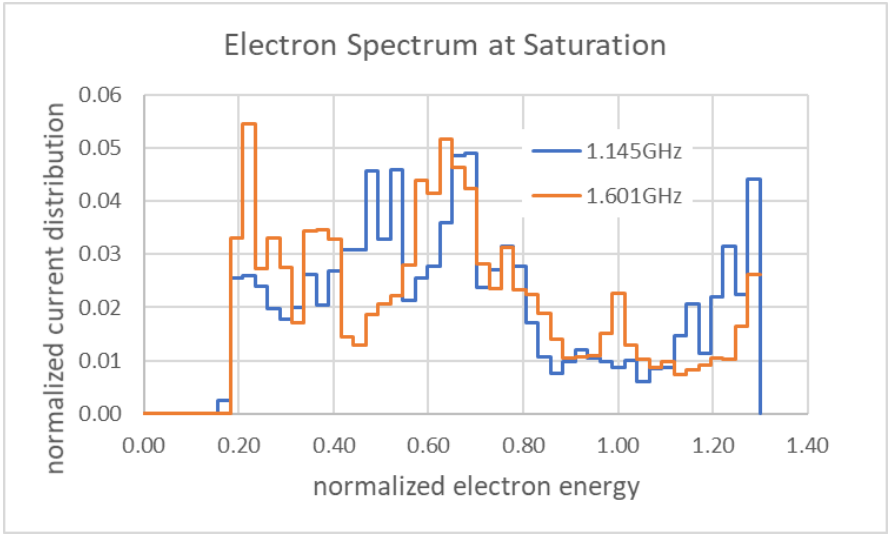
Electron Spectrum Variation – Frequency and Drive





- Electron spectrum strongly dependent on frequency and drive
- Solution: 5-stage collector

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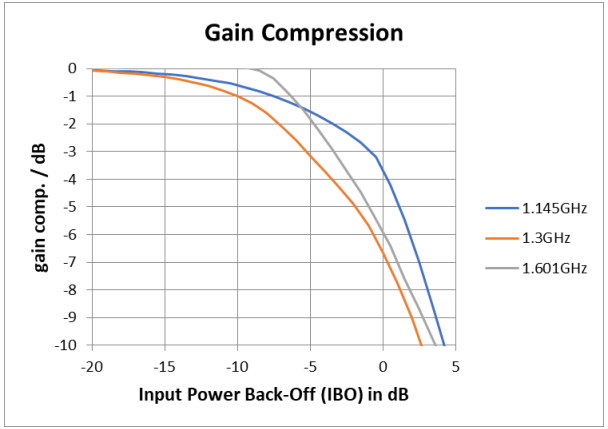
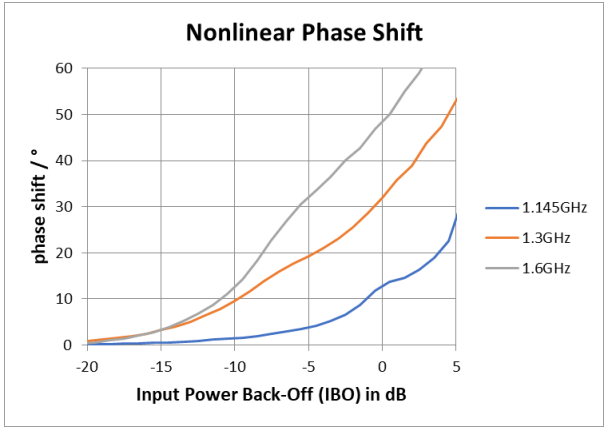
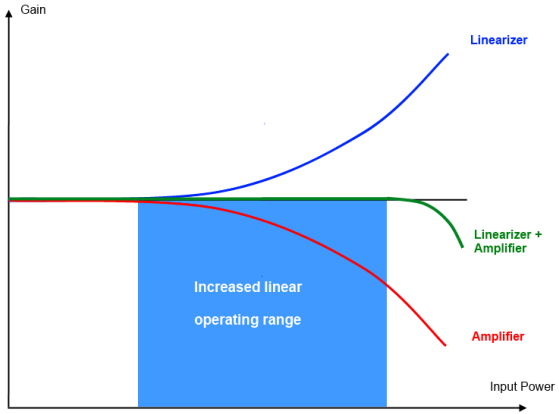
Nonlinear Distortions and Linearizer







- **TWT: Nonlinear signal distortion, e.g. gain compression, phase compression etc.**
- **Compensation by „Linearizer“ using pre-distortion**
  - Designed by TESAT
  - Complicated by frequency-dependence of TWT distortions

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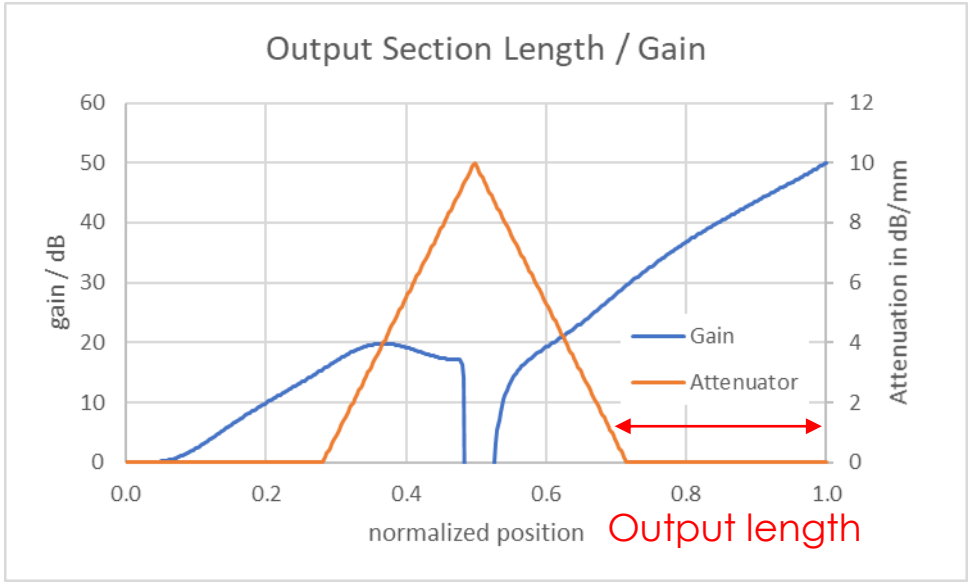
Output Length

- **RF signal needs to be restored after central attenuator (from beam modulation)**
- **Minimum electric length necessary**
  - Long output section favorable for low-band output power
  - Trade-off with output-section feedback loop („hotmatch“)



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Current Development Status and Outlook

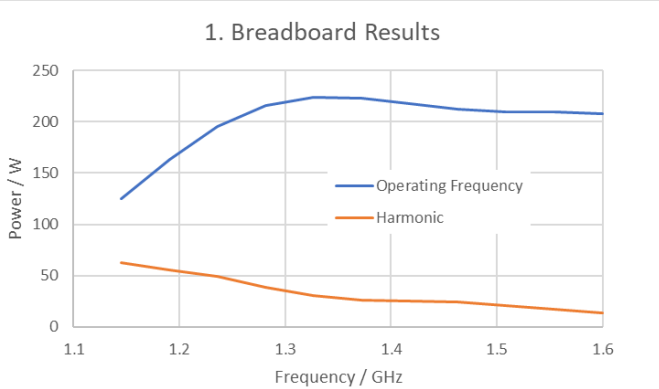
1. Breadboard: Output power at lower band edge below spec

- Output section of delay line too short

2. Breadboard currently assembled, results expected end of September

- Longer delay line

3. Breadboard: Mass reduction



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Questions?

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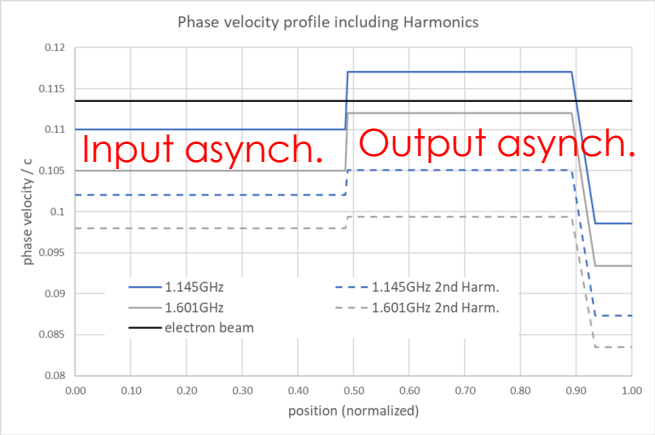
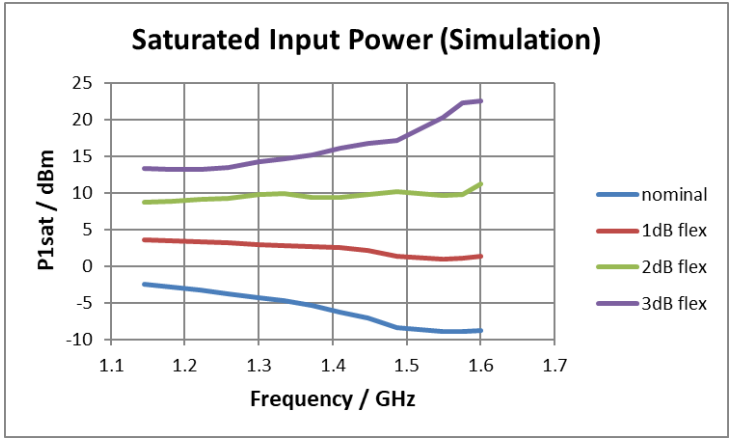
Gain Variation versus Reduced Operating Power (a.k.a. „flex“)





- **Asynchronous operation in output balanced by reverse asynchronous operation in input section**
  - Ideally: Input power for saturation flat over operating band
- **Flex operation achieved by reducing beam current**
- **Reduced beam current alters beam-wave synchronicity, gain variation increased**

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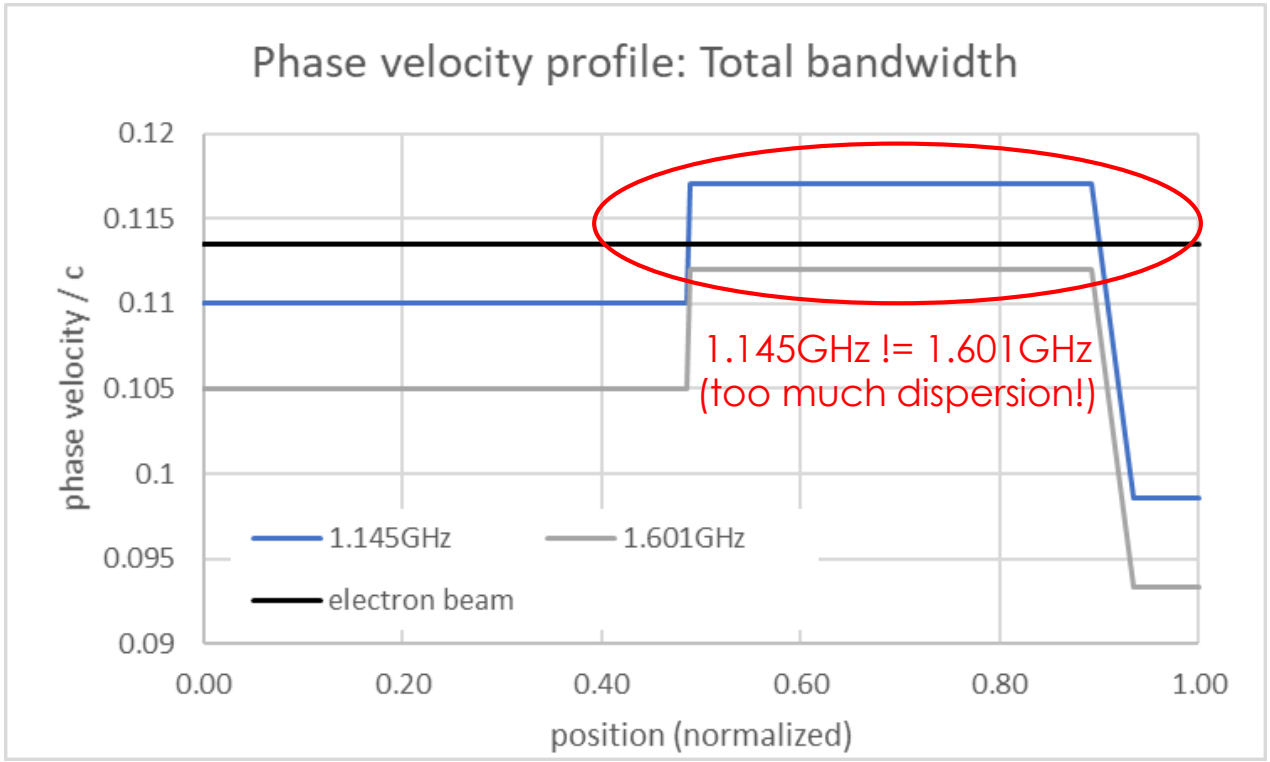

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