Tentative Design of a W-Band Hollow-Beam Klystron for Frequency Tripling

Jiwei Nie | Theoretische Elektrotechnik | Technische Universität Berlin | 5th International Vacuum Electronics Workshop 2016, Bad Honnef, Germany

Technische Universität Berlin

Overlook of W-Band Klystron

Output Cavity Design

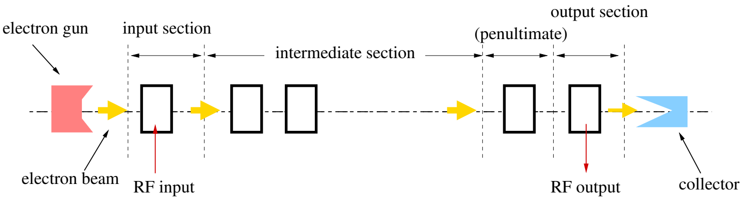
Idler Cavity Design

Input Cavity and Drift Length of Electron Beam

Linearity of Klystron

Conclusions

Overlook of W-Band Klystron (I)



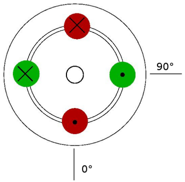
- **function**: frequency tripling $f_{input} = 30\,\mathrm{GHz} \rightarrow f_{output} = 90\,\mathrm{GHz}$
- **electron beam**: modulated hollow beam with $U_0 = 50\,\mathrm{kV}(\beta = 0.412)$ and $I_0 = 1\,\mathrm{A}$
- **cavities**: coaxial resonators with input, idler and penultimate in TM_{110}-mode, output in TM_{310}-mode
- **beam pipe**: coaxial form

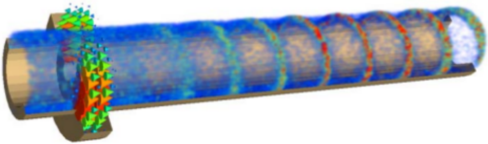
Overlook of W-Band Klystron (II)

short introduction to modulated hollow beam

A modulated hollow beam has three components:

- hollow beam
- resonant cavity operating in rotating TM_{m10}-mode
- hollow beam modulated by rotating mode in propagation direction

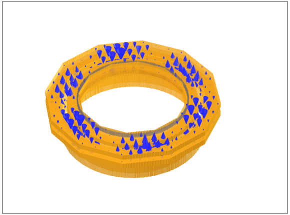


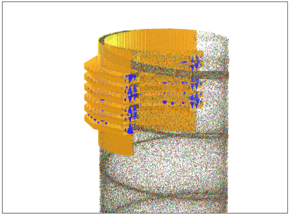


Technische Universität Berlin

Output Cavity Design (I)

- output cavity in prism form with 12 edges
- tuning ring instead of output waveguides
- modulation depth of beam is 5%
- coupled gap cavity in π-mode



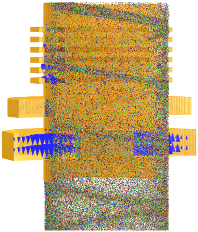


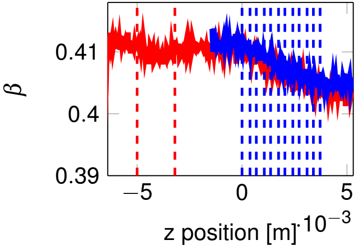
cavity	P_{out}/P_{in} [%]
two gaps	0.8%
four gaps	1.32%
six gaps	1.986%

Output Cavity Design (II)

- Output cavity with "penultimate"cavity

the "next to the last"cavity, operates in TM_{110}-mode, inductively excited, improves the bunch quality





output efficiency of six gap cavity with penultimate: 2.36%

Idler Cavity Design (I)

- improve the gain of the klystron
- inductively excited for modulation enhancement

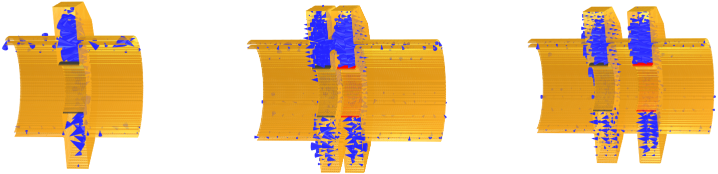
$$\Phi = \tan^{-1}\left(\frac{\omega_0^2 - \omega^2}{\omega_0 \omega / Q}\right) \tag{1}$$

Beam under Investigation with initial modulation depth of 1%

Φ	modulation depth [%]	power loss [%]
65°	2.3543	0.025
70°	2.1359	0.016
75°	1.8689	0.009
80°	1.6504	0.006
85°	1.3592	0.002

Idler Cavity Design (II)

- Three Idler Types:
  Single Idler , Coupled Idler and Clustered (but not Coupled) Idler

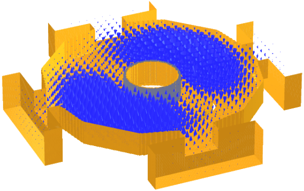


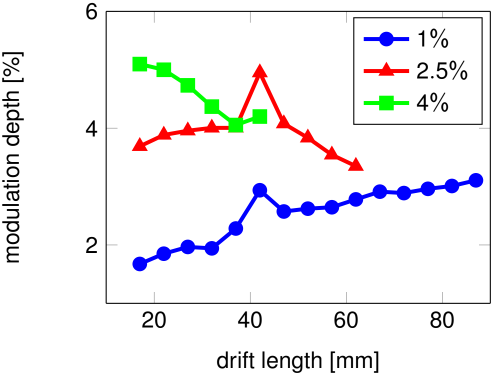
$\Phi = 80^\circ, Q = 1000$, modulation depth=1%

idler type	modulation depth in %
one single cavity with Q	1.65
coupled cavities with half Q	1.38
clustered cavities with half Q	1.58
clustered cavities with Q	2.67

Input Cavity and Drift Length of Electron Beam

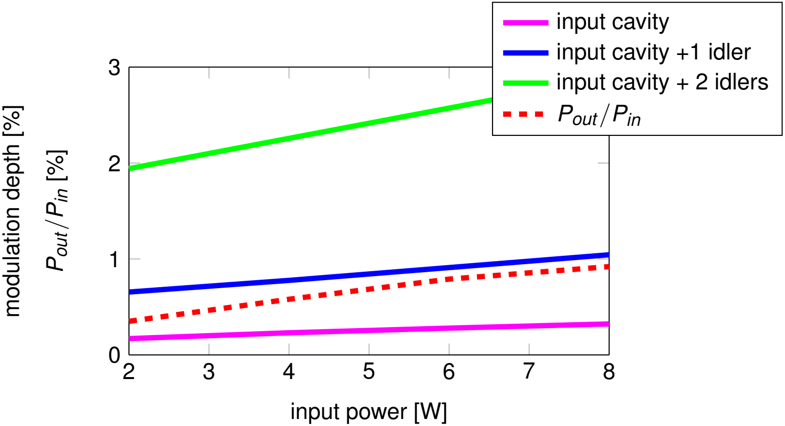
- input cavity in TM_{110}-mode with four power feeding waveguides
- after different drift lengths electron beam with initial modulation depth of 1%,2.5% and 4% achieve different new depths in clustered idler





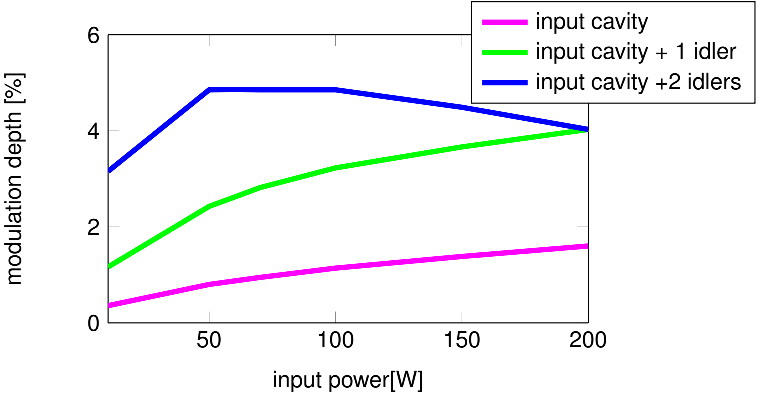
Linearity of Klystron (I)

– linear area



Linearity of Klystron (II)

– non-linear / saturation area



Conclusions

- **Advantages**
  frequency tripling in kW level
  linearity in known area
  easy to manufacture
- **Disadvantages**
  low efficiency
  difficult to build numeric model

○ This project is founded by Deutsche Forschungsgesellschaft.