

# Experiments with a single-mode laser diode pumped NPRO

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*and*

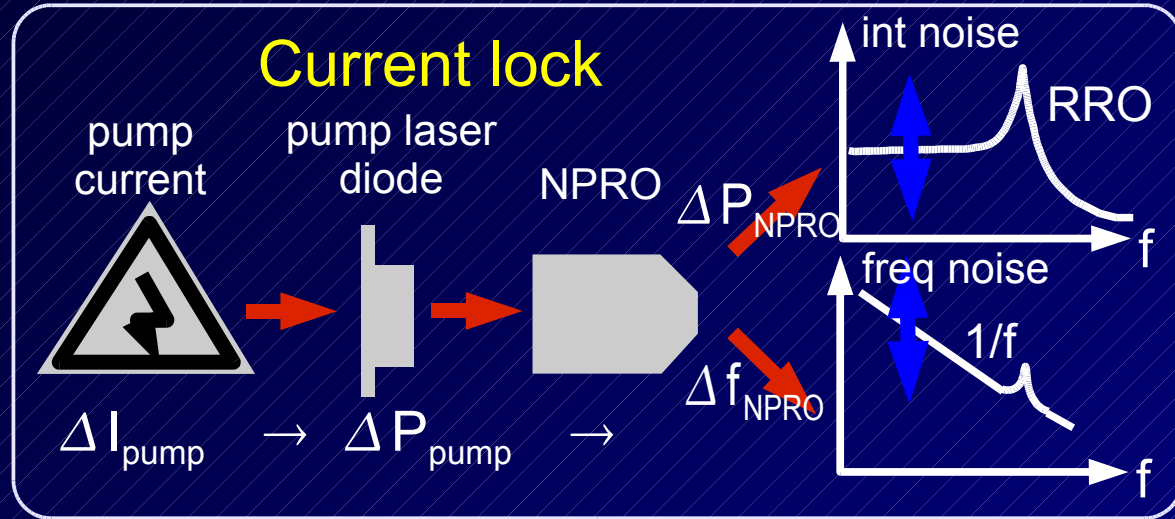
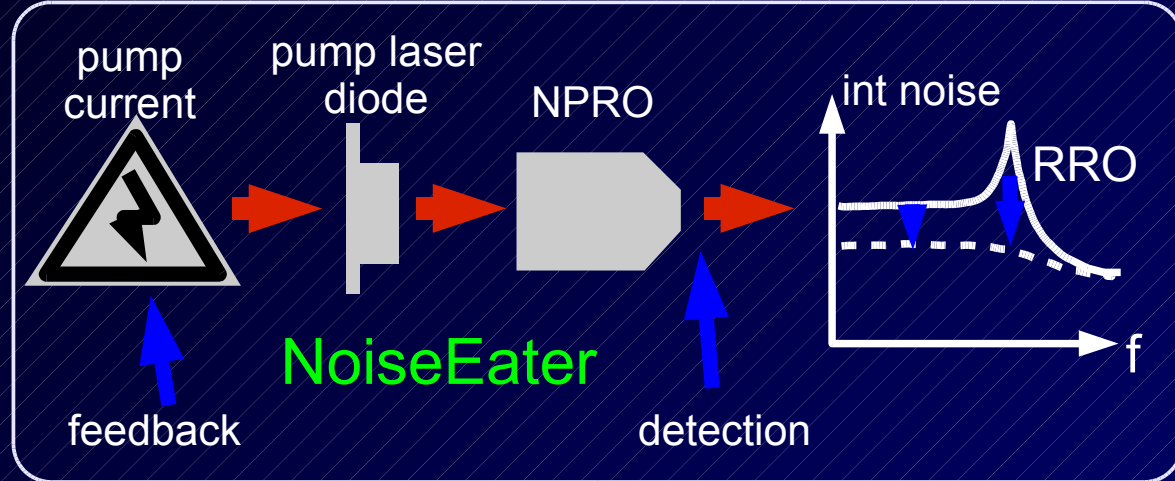
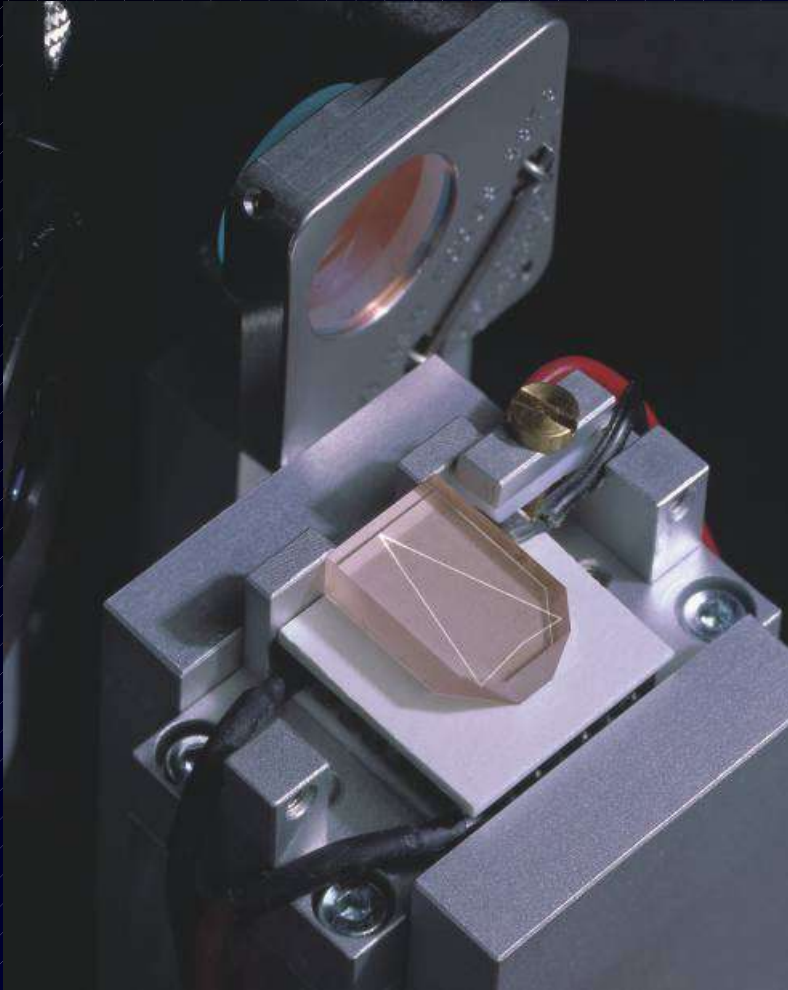
Institute for atomic- and  
molecular physics  
(section spectroscopy)

Callinstr. 38, 30167 Hannover



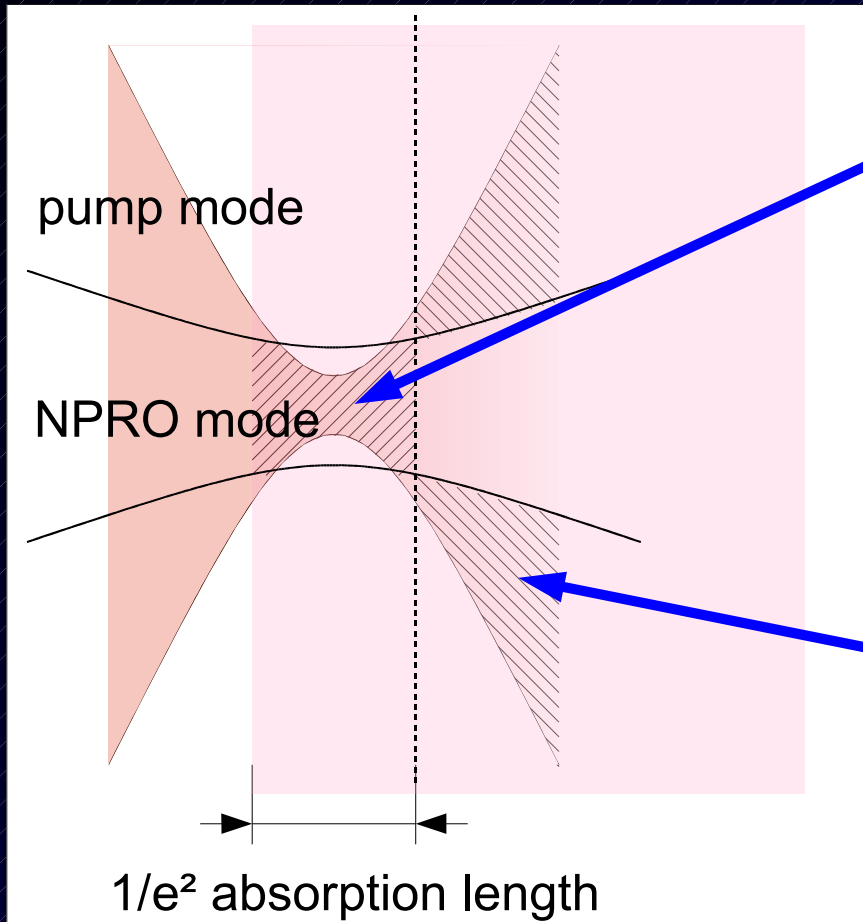


# Non-planar ring oscillator (NPRO)





# Pump- and laser mode in multi-mode pumped NPRO



overlap: pump noise couples into NPRO frequency and intensity noise

$$\Delta T \rightarrow \Delta n \wedge \Delta L \rightarrow \Delta L_{\text{opt}} \rightarrow \Delta f_{\text{NPRO}}$$

$$\Delta \sigma \rightarrow \Delta P_{\text{NPRO}}$$

$$\Delta \sigma \rightarrow \Delta n \rightarrow \Delta f_{\text{NPRO}}$$

outside overlap region: pump noise couples into NPRO frequency noise only

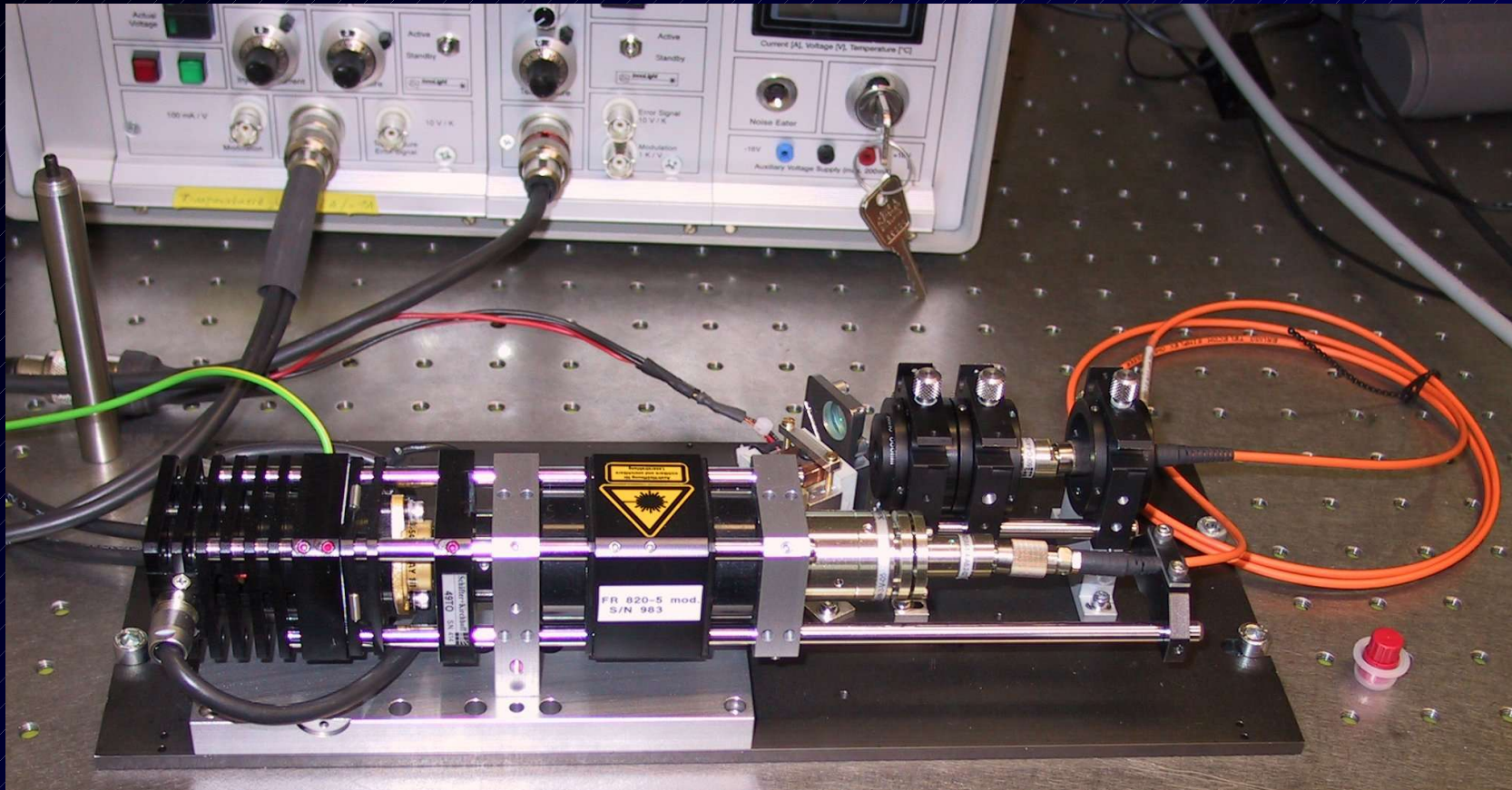
$$\Delta T \rightarrow \Delta n \wedge \Delta L \rightarrow \Delta L_{\text{opt}} \rightarrow \Delta f_{\text{NPRO}}$$

Simultaneous stabilisation



Single-mode pumped NPRO  
schematic setup

# Single-mode laser diode pumped NPRO



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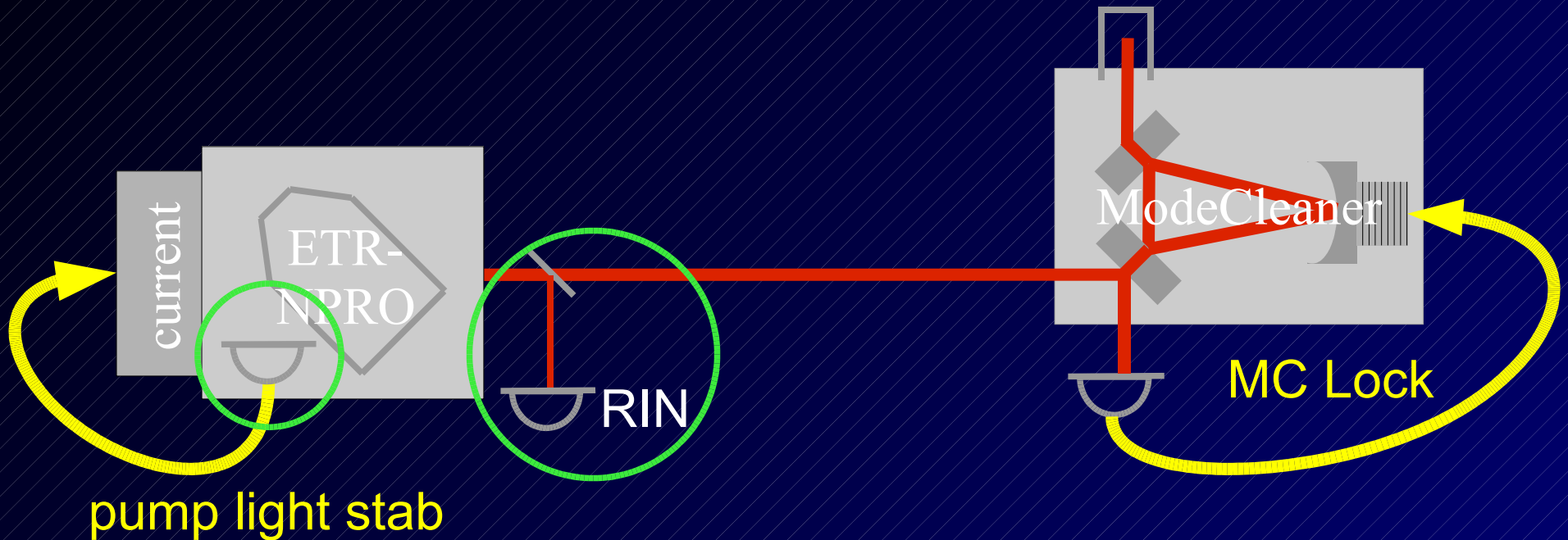


Simultaneous stabilisation



Single-mode pumped NPRO  
pump light stabilisation

## Pump light stabilisation: experimental setup



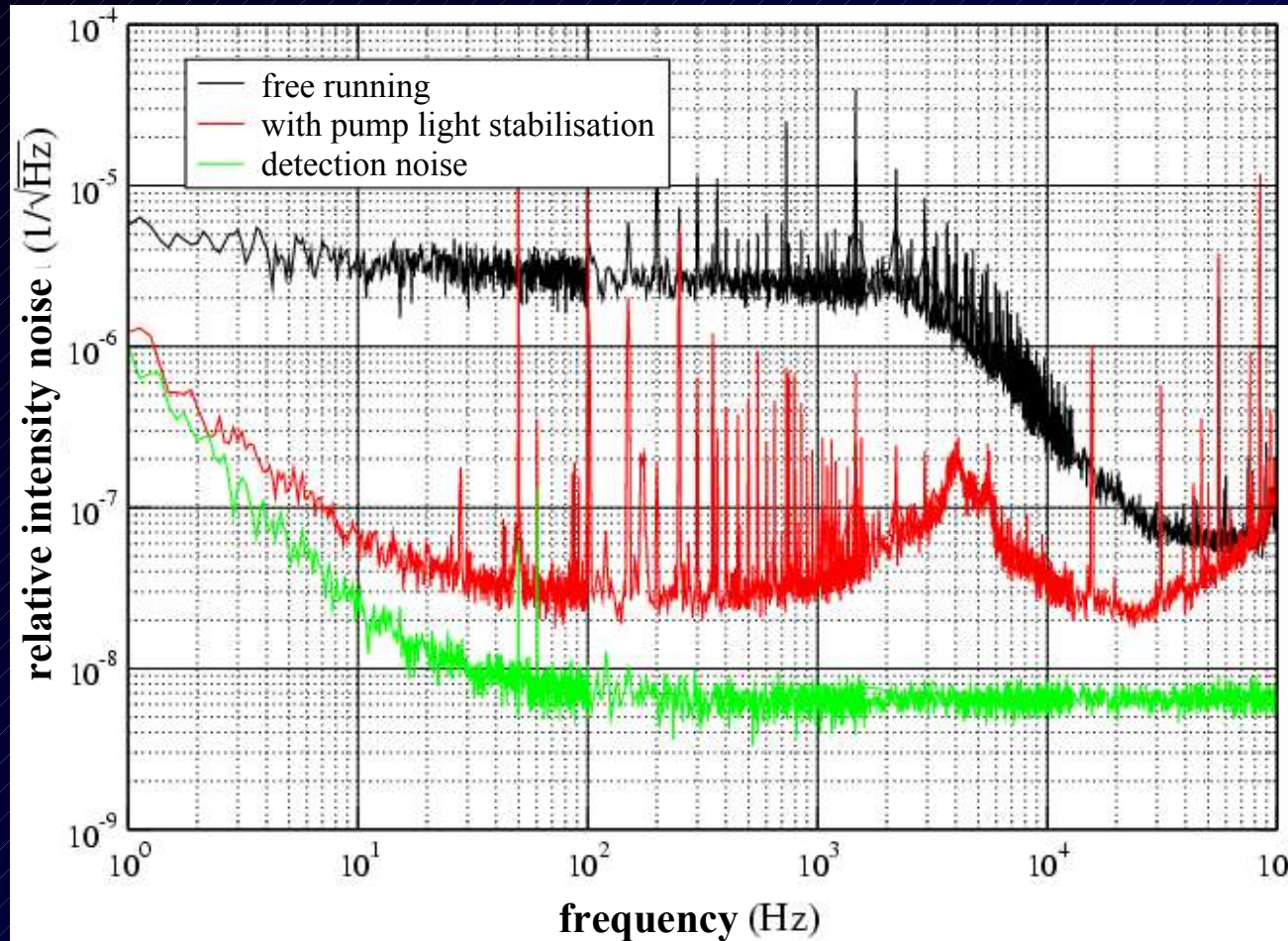
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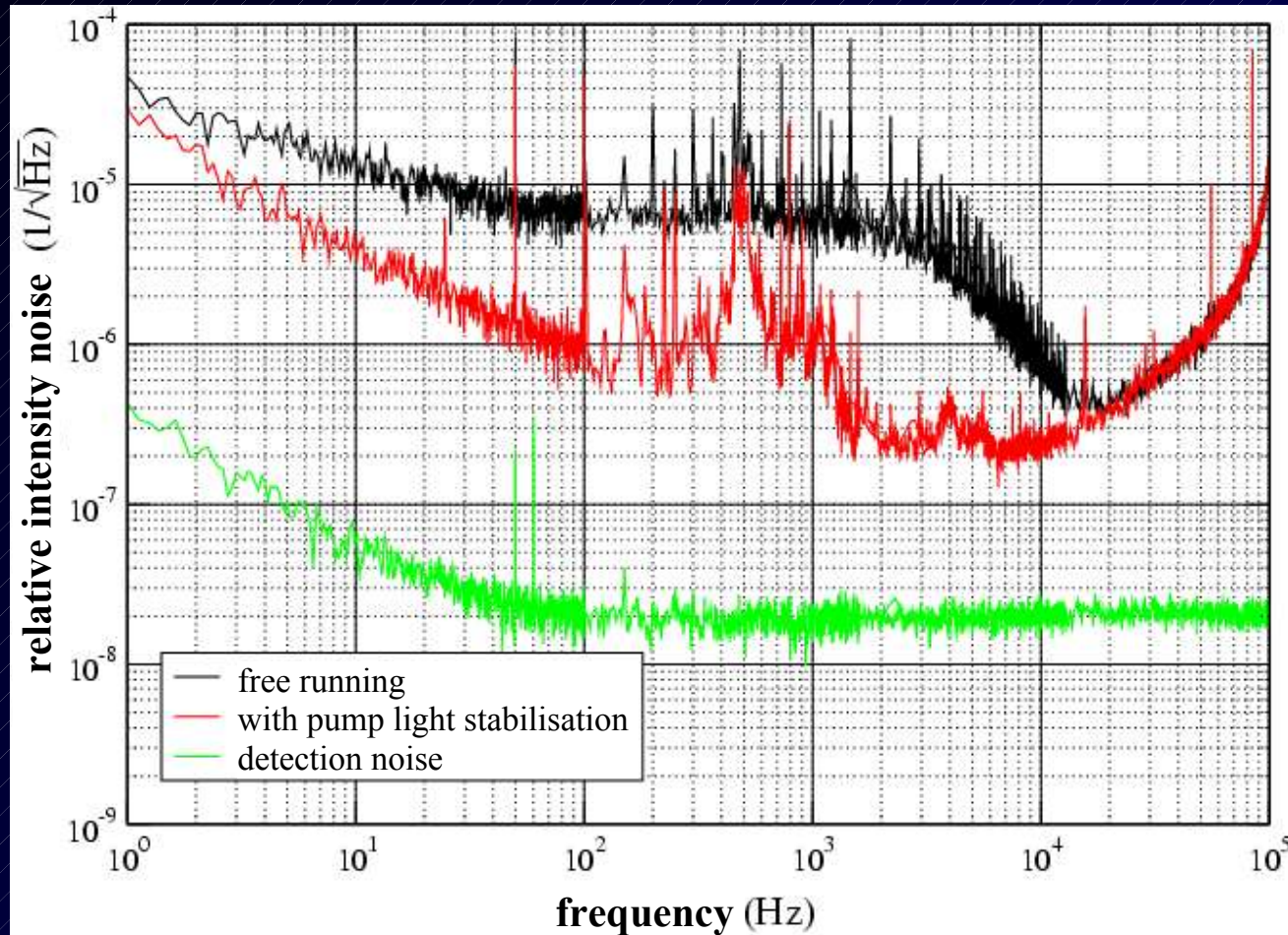


# Pump light stabilisation: intensity noise reduction of the pump laser diode



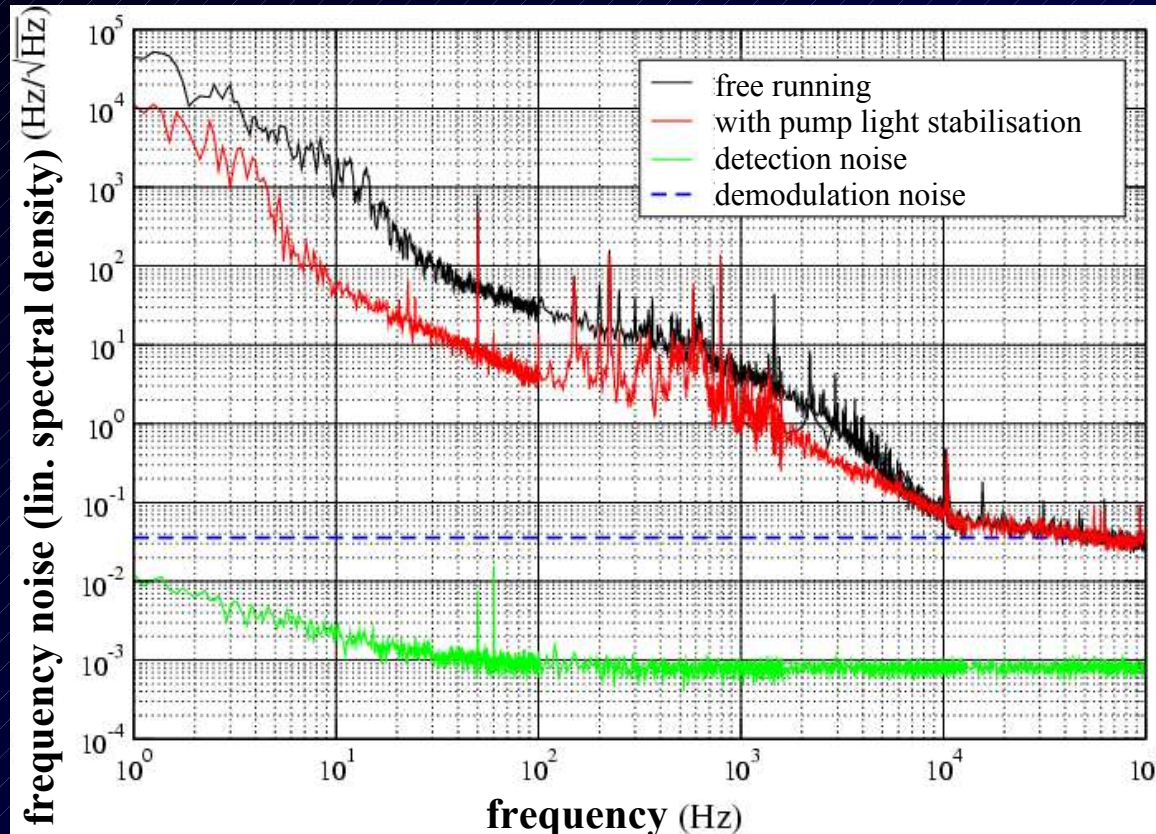


# Pump light stabilisation: intensity noise reduction of the NPRO





# Pump light stabilisation: simultaneous frequency noise reduction



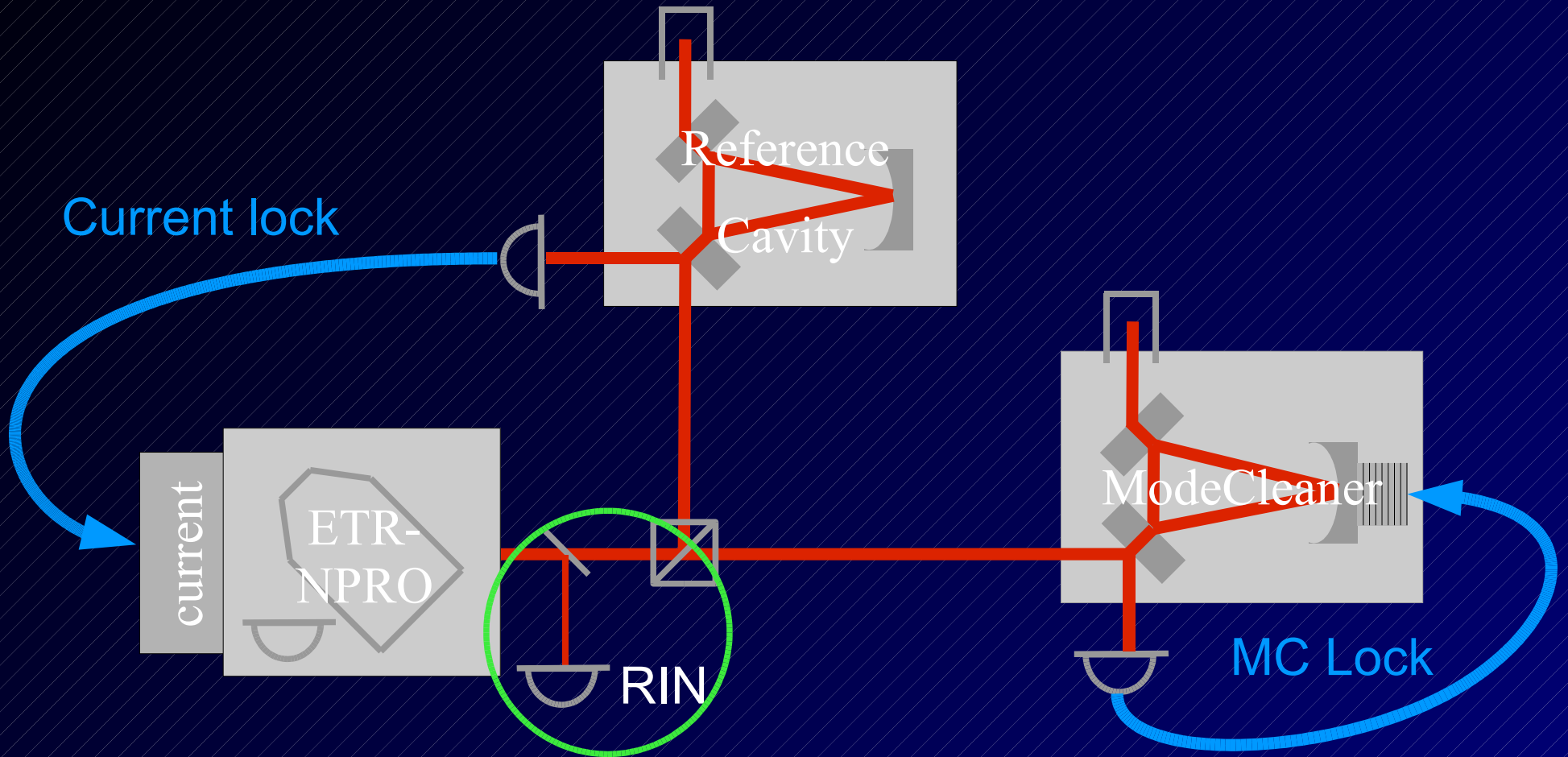
Heurs et al., “Intensity and frequency noise reduction of a Nd:YAG NPRO via pump light stabilisation”, to be submitted to Appl. Phys. B





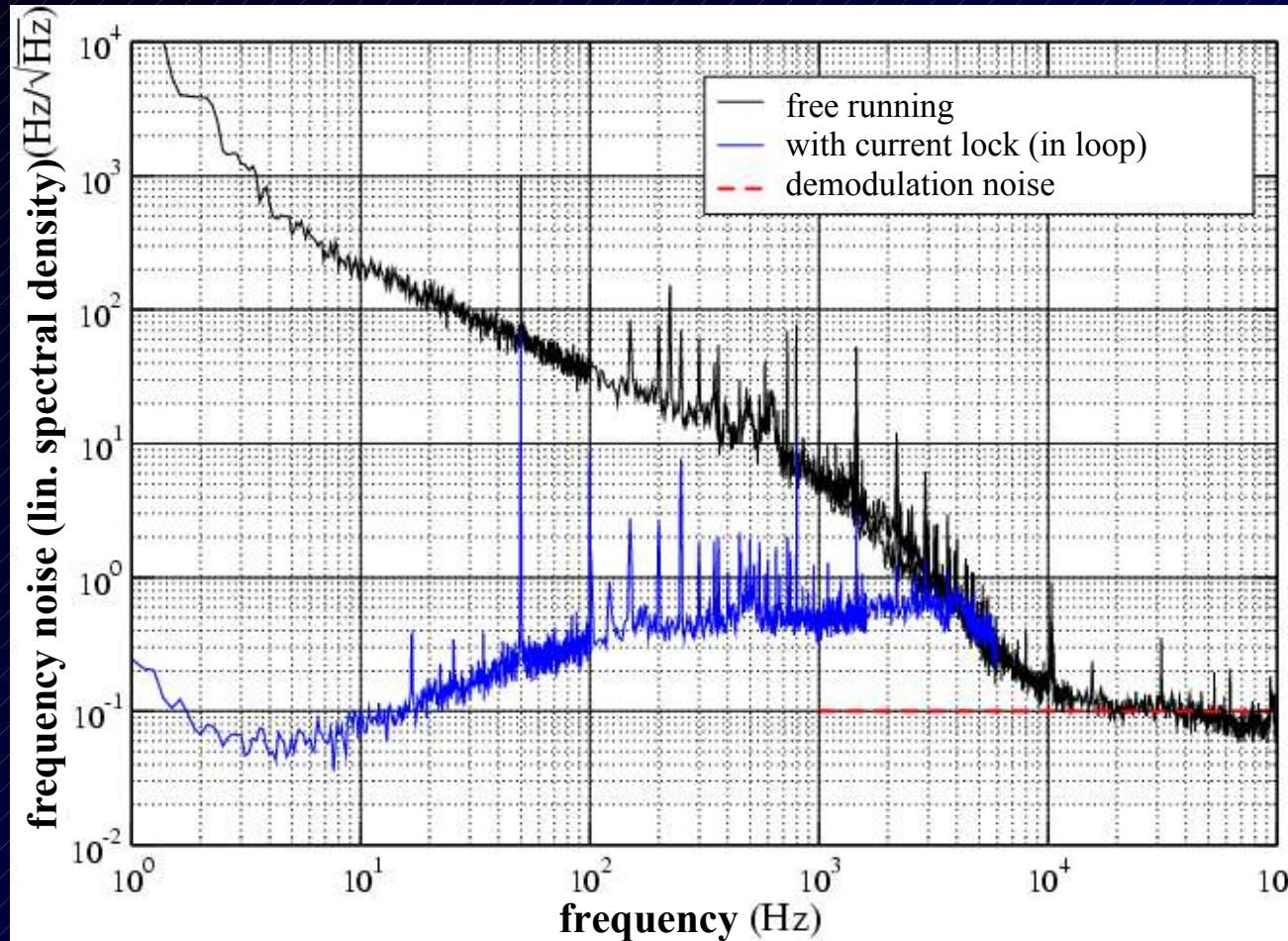


## Current lock: experimental setup



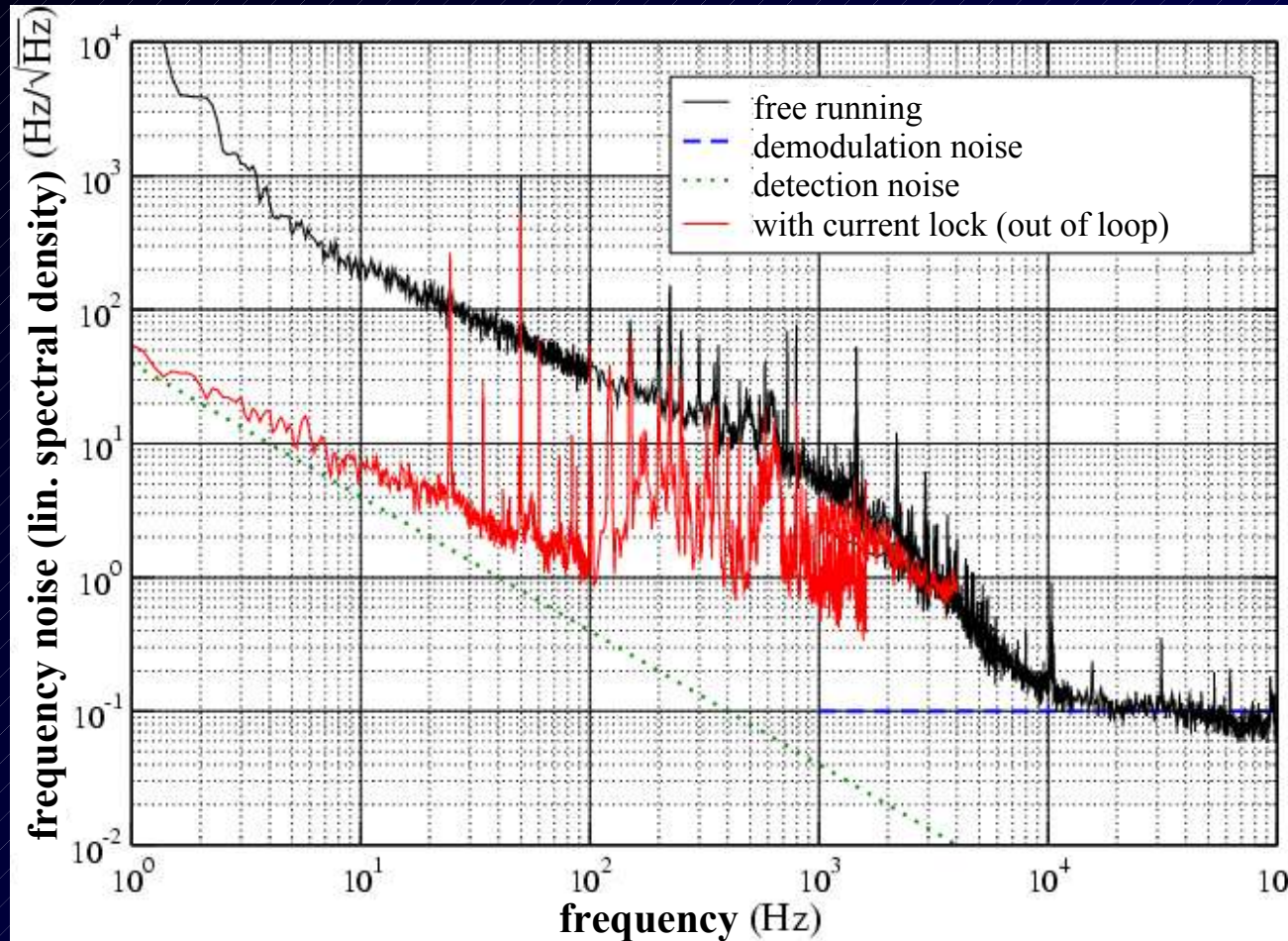


# Current lock: frequency noise reduction (in loop)



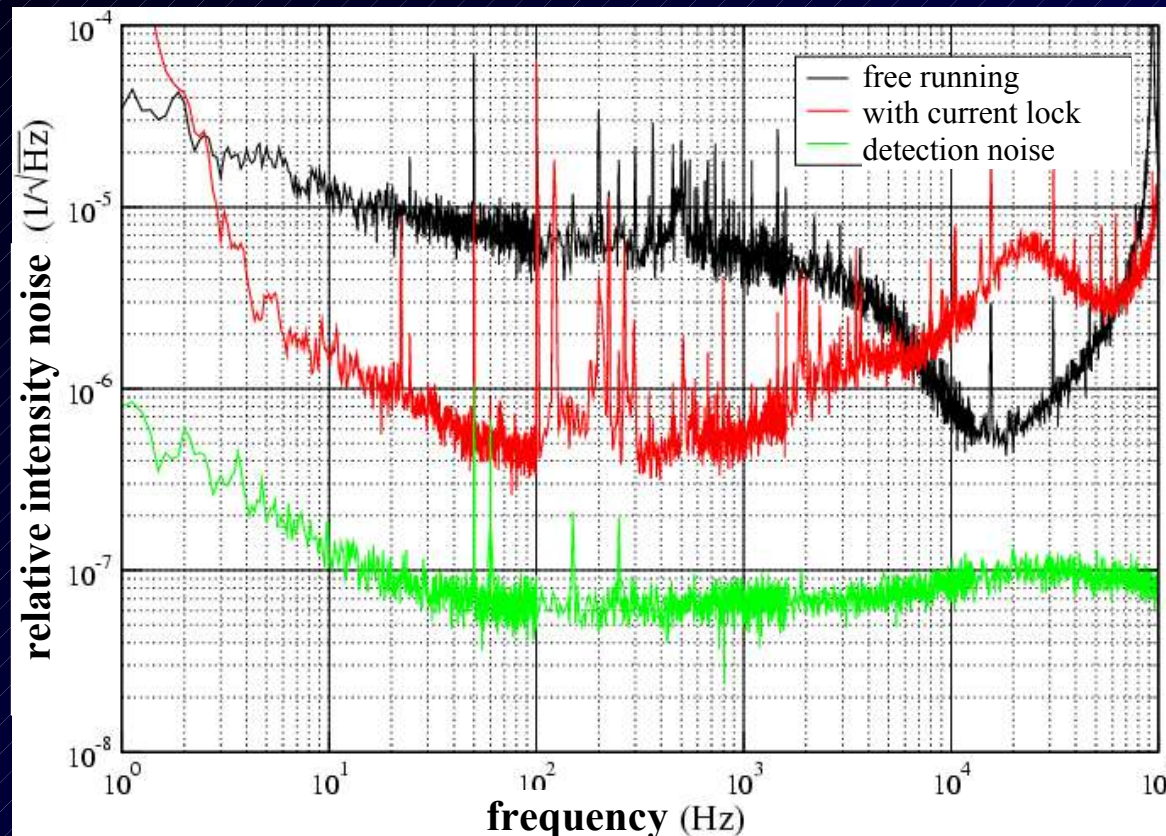


# Current lock: frequency noise reduction (out of loop)





# Current lock: simultaneous intensity noise reduction



Heurs et al., “Simultaneously suppressing frequency and intensity noise in a Nd:YAG nonplanar ring oscillator by means of the current-lock technique”, *Opt. Lett.* **29**, 2148 (2004)

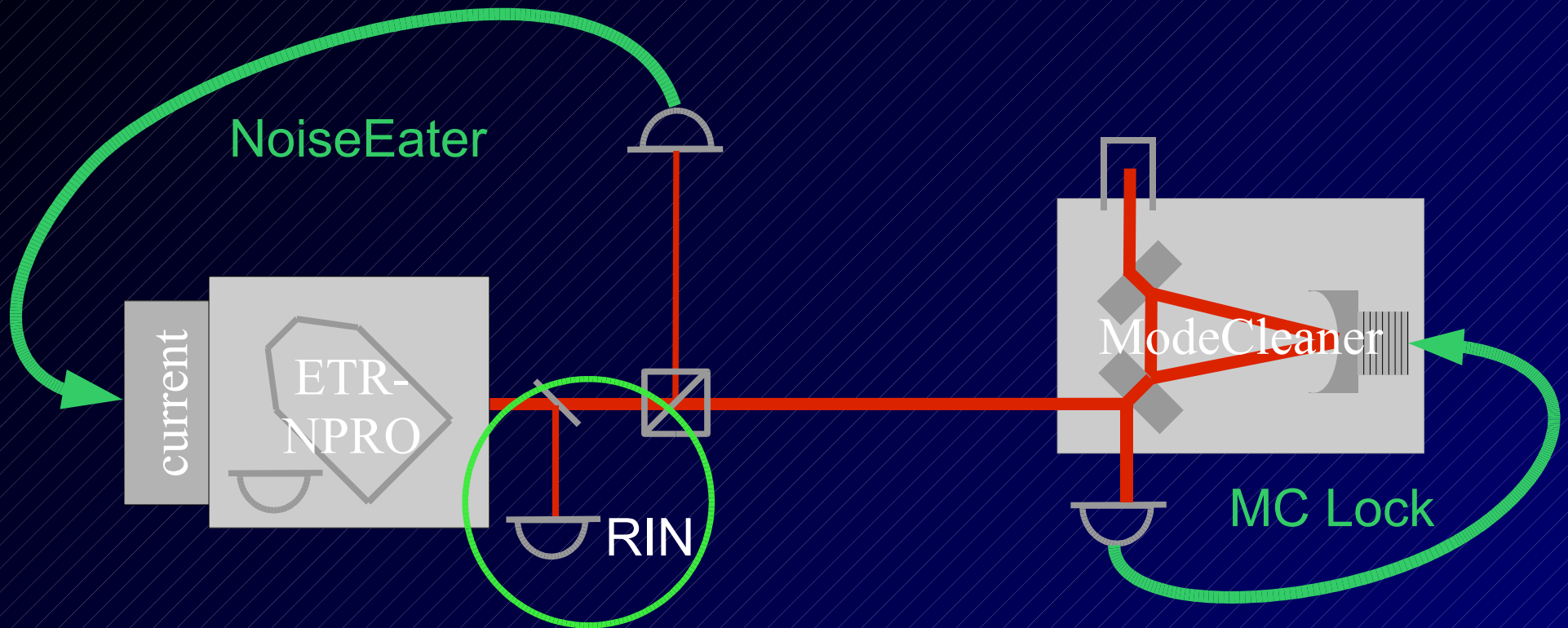


Simultaneous stabilisation



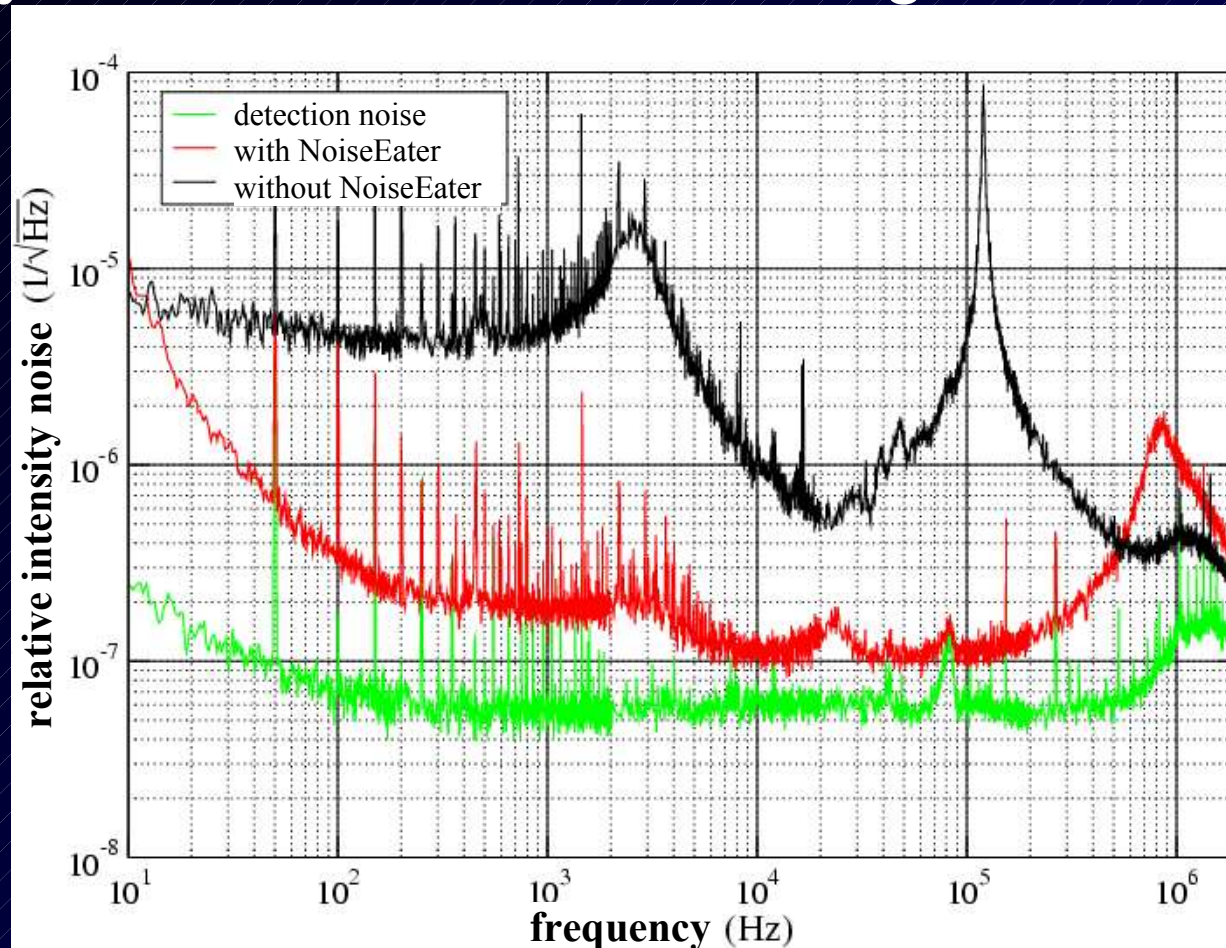
Single-mode pumped NPRO  
increasing the bandwidth

# Increasing the bandwidth: a **NoiseEater** for the single-mode pumped NPRO



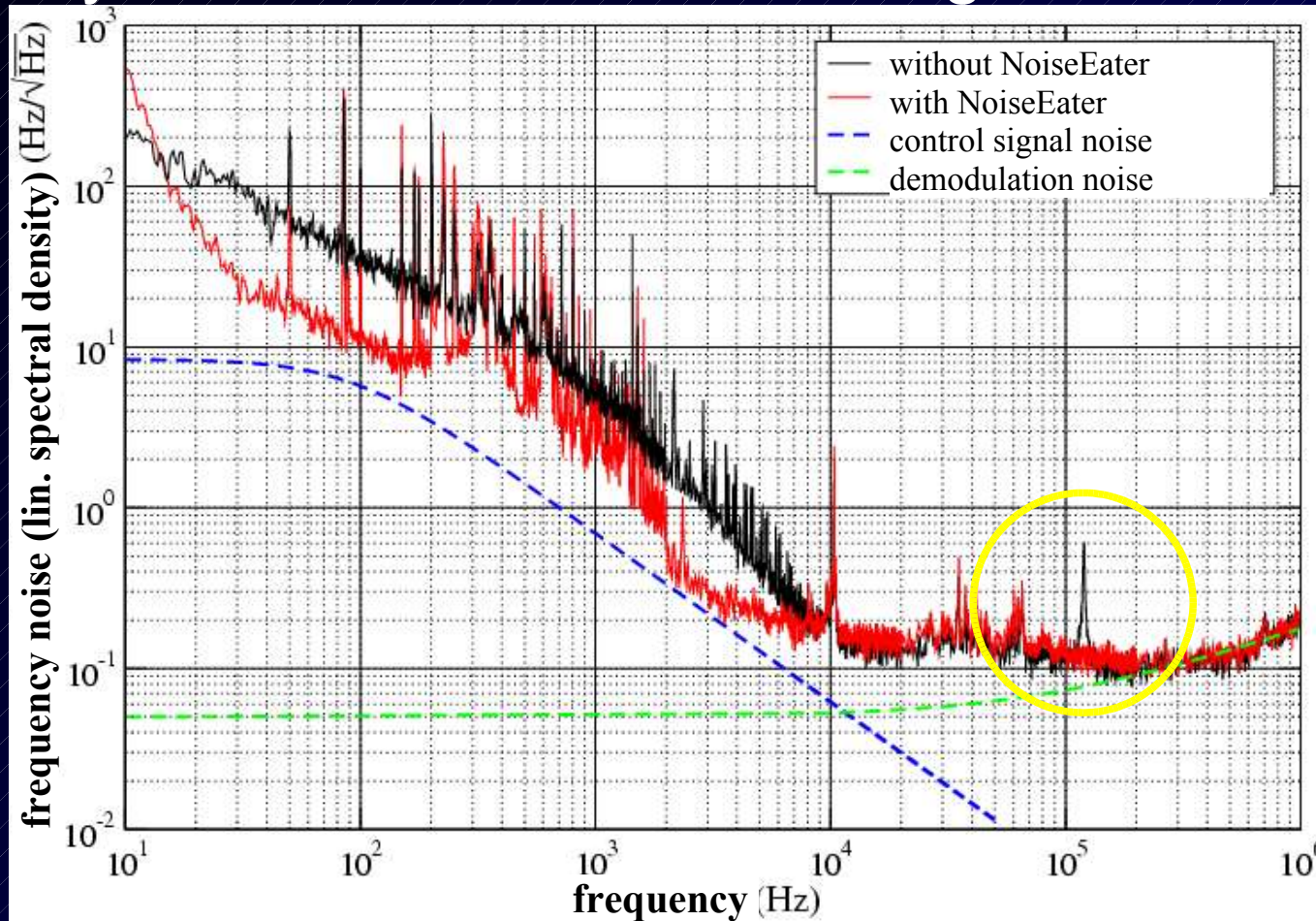


# Increasing the bandwidth: intensity noise reduction of the single-mode NPRO





# Increasing the bandwidth: frequency noise reduction of the single-mode NPRO





## Résumé

### Pump light stabilisation:

Reduction of NPRO intensity noise + simultaneous reduction of NPRO frequency noise  $\sim 20$  dB

### Current Lock:

Reduction of NPRO frequency noise + simultaneous reduction of NPRO intensity noise  $\sim 30$  dB

### NE-Experiment:

Reduction of NPRO intensity noise + simultaneous reduction of NPRO frequency noise with a bandwidth above the RRO





FIN!



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# Weitere Folien zur näheren Erläuterung



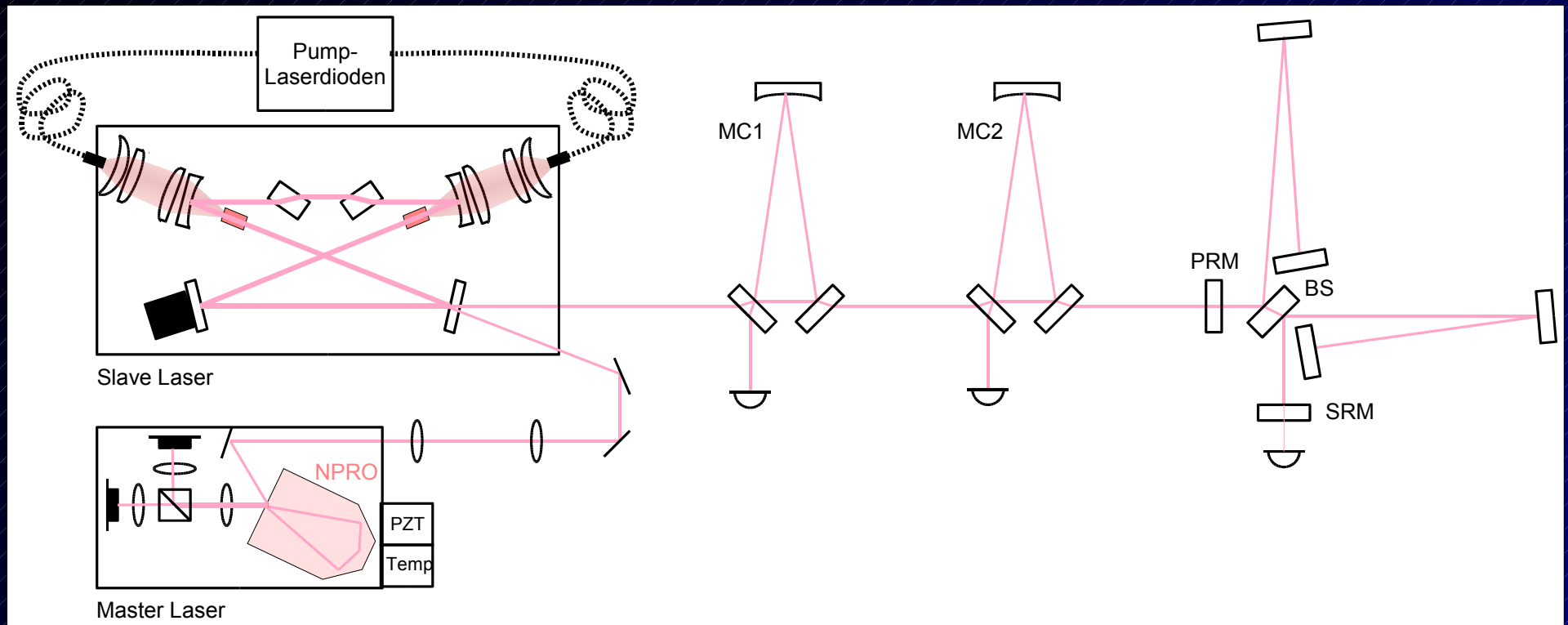
## Ausblick

- Current Lock am single-mode gepumpten NPRO über RRO
- Erhöhung der Pumpleistung single-mode gepumpter NPRO  
→ Einsatz als Master Laser!
- Non-Demolition Messungen durch Korrelationen im single-mode gepumpten NPRO!?





# Überblick: Schematischer Aufbau von GEO 600





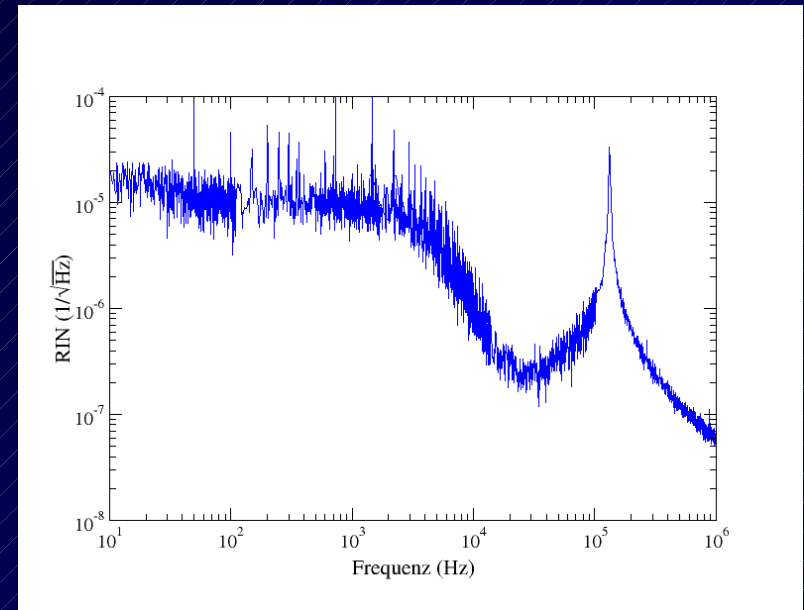
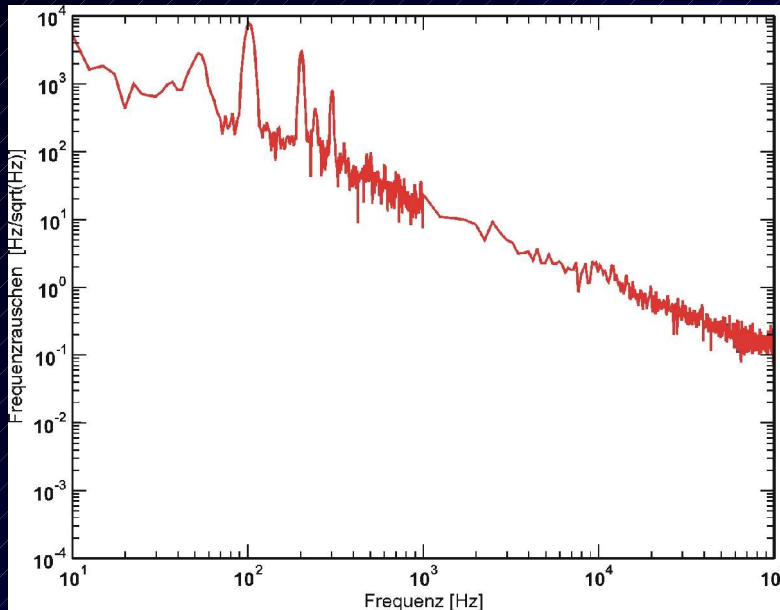
# Korrelation zwischen Frequenz und Leistung im NPRO

“Weißes Pump-Leistungsrauschen treibt  $1/f$  **Frequenzrauschen** im NPRO.”  
(Day 1990)

“Unterhalb der RRO treibt weißes Pump-Leistungsrauschen auch weißes NPRO-**Leistungsrauschen**.” (Harb et al. 1997)

$$\Delta P_{\text{pump}} \rightarrow \Delta n \wedge \Delta L_{\text{opt}} \rightarrow \Delta f_{\text{NPRO}} \sim 1/f$$

$$\Delta I_{\text{pump}} \rightarrow \Delta P_{\text{pump}} \rightarrow \Delta P_{\text{NPRO}} \text{ für } f \ll \text{RRO}$$



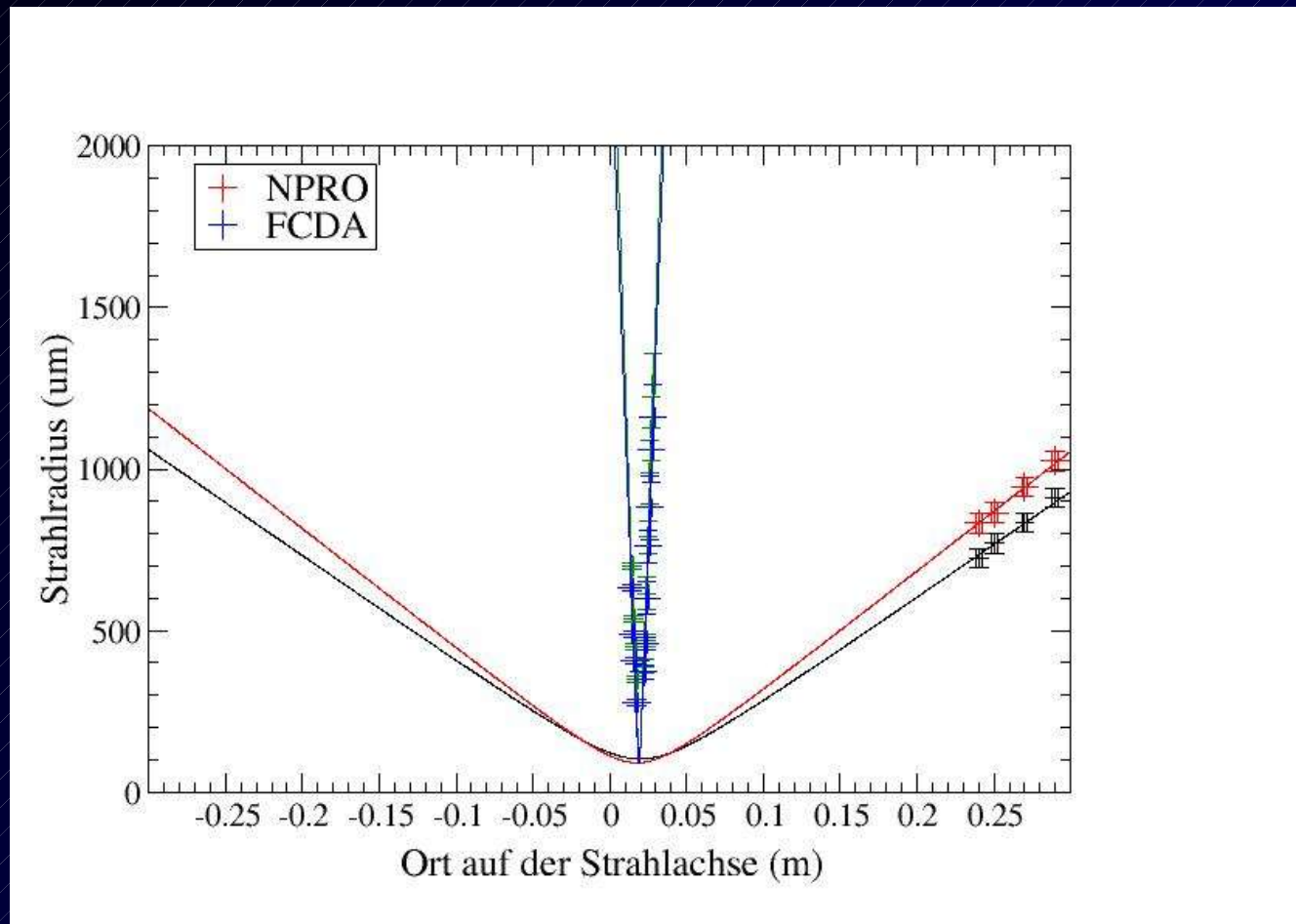


# Frequenzstabilisierung (Current Lock) am NPRO

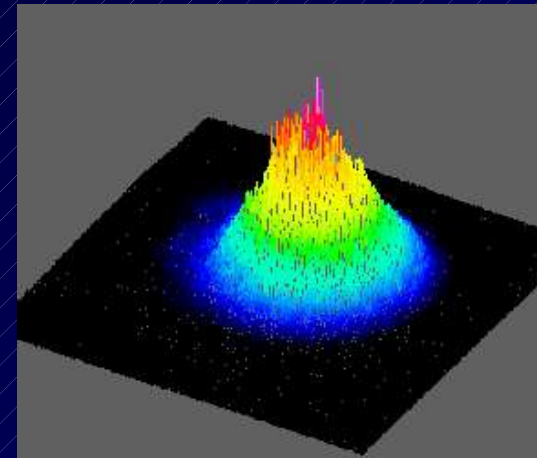
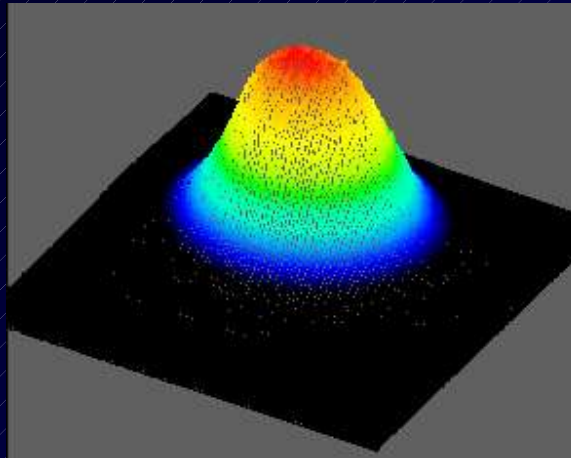
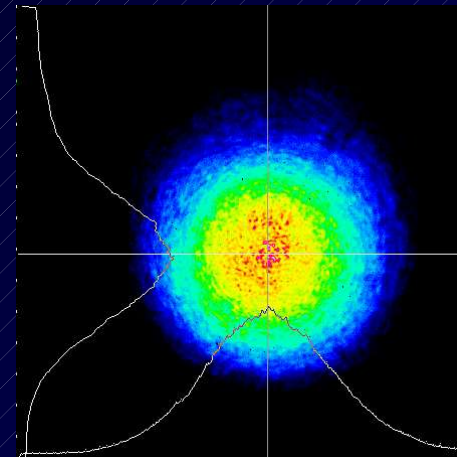
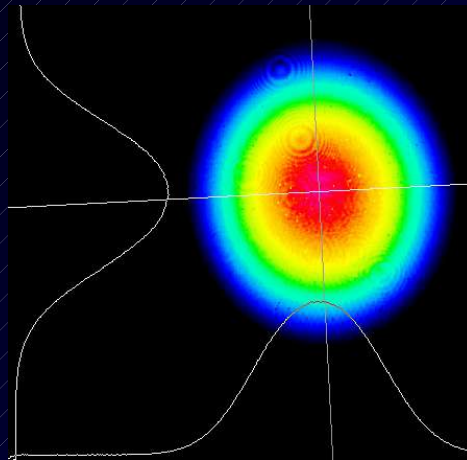
(Wilke et al., Opt. Lett. 2000)



# Modenüberlapp von Pump- und Lasermode im NPRO



# Intensitätsverteilung von NPRO und Laserdiodenarray

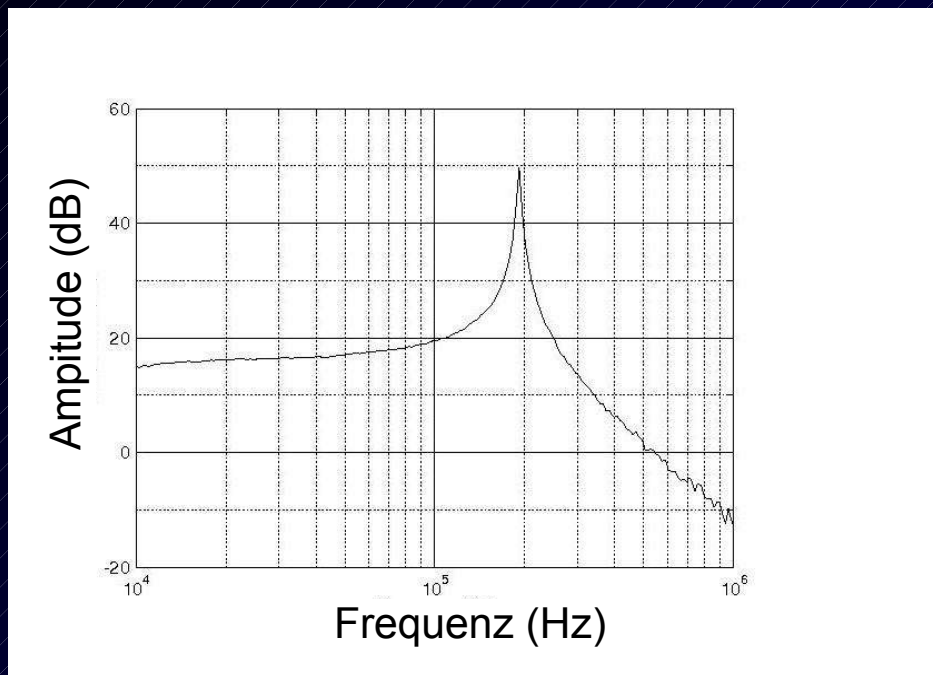




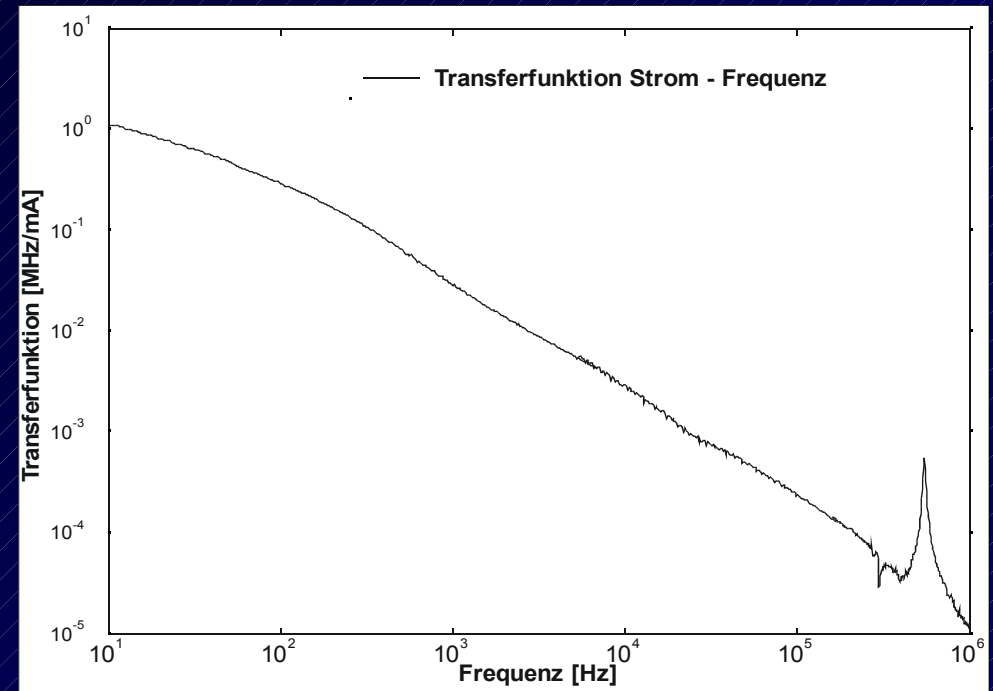
# Wirkungsweise des Current Lock

Es gibt beim NPRO definierte Transferfunktionen:

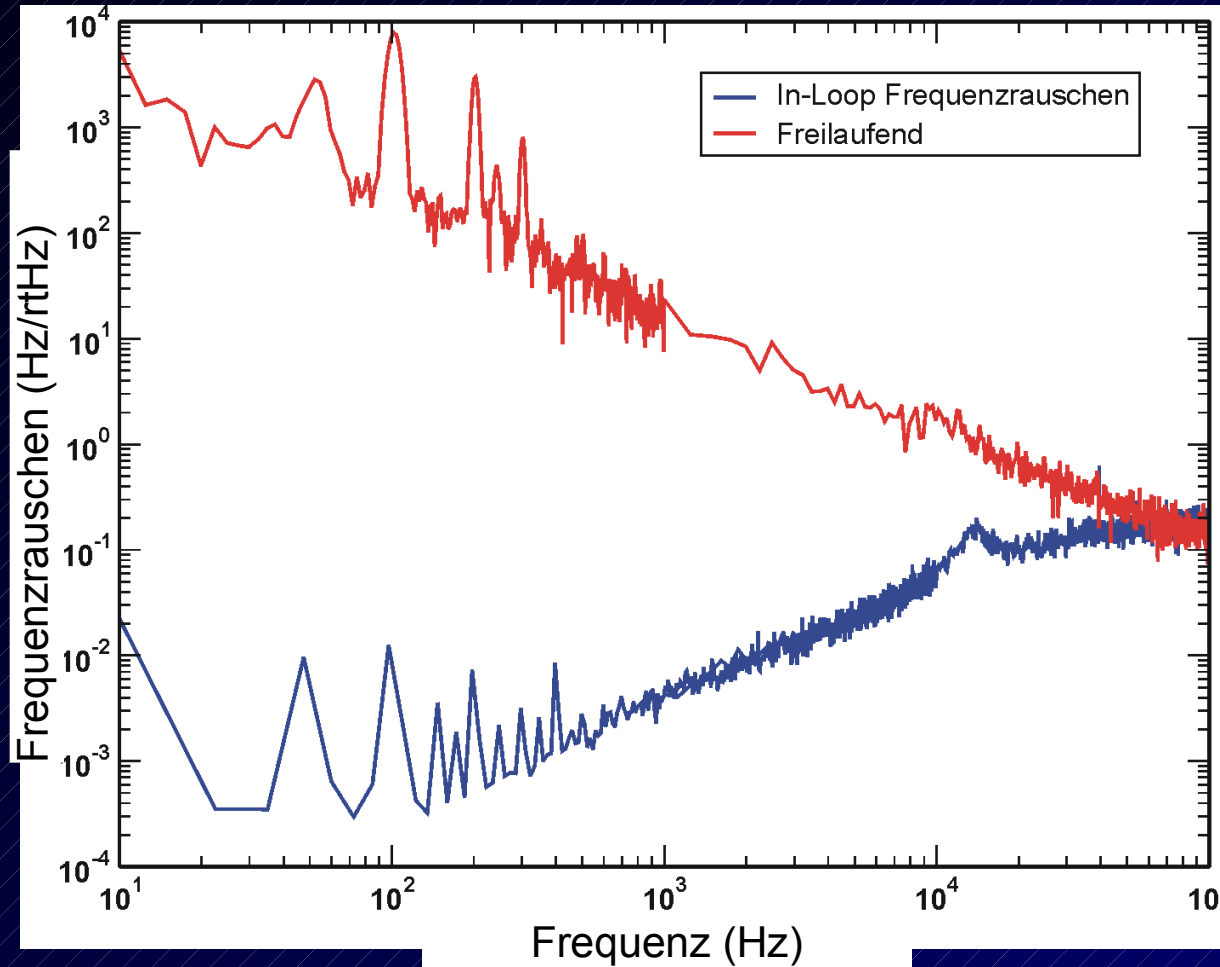
TF Pumpstrom -> NPRO-Leistung



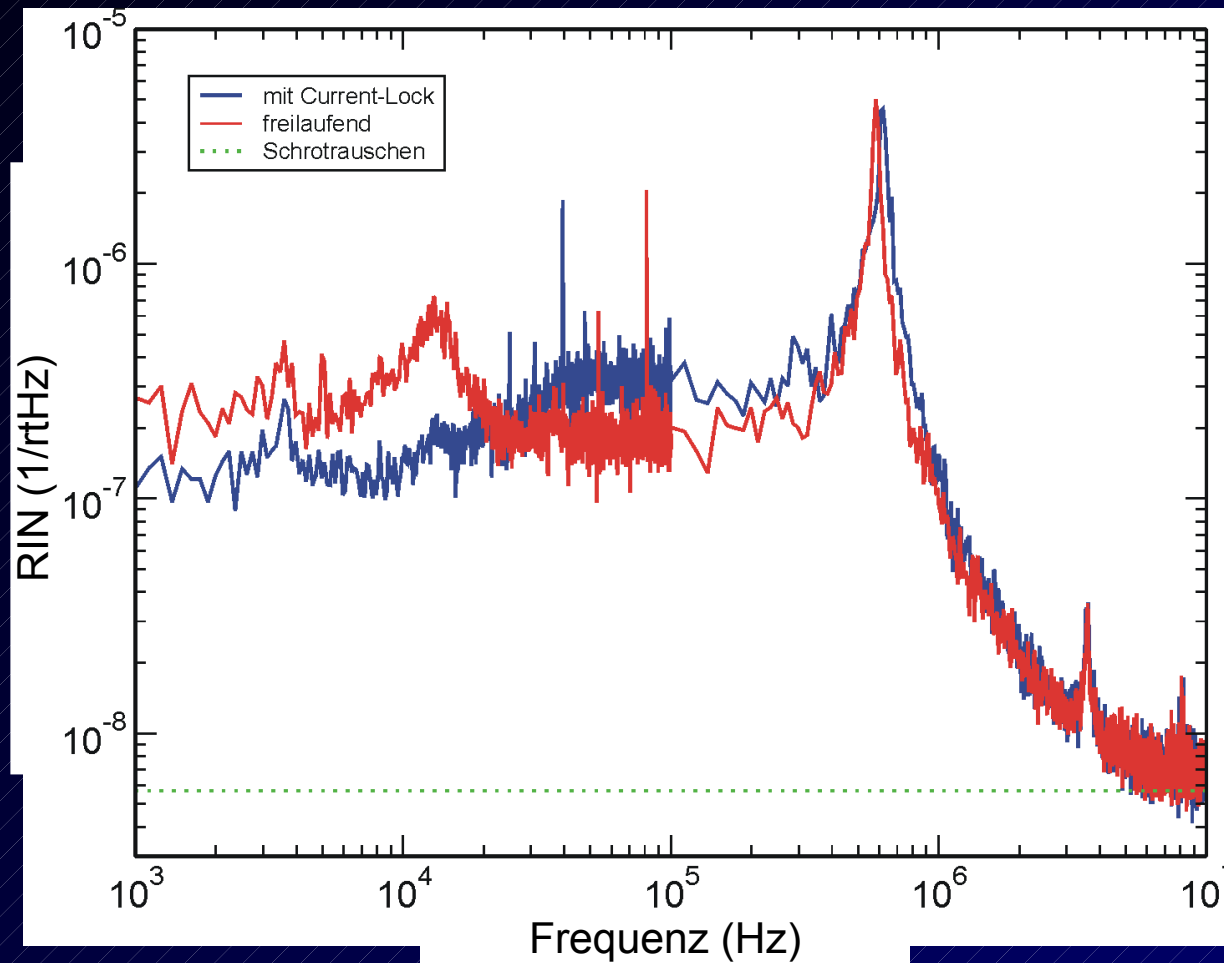
TF Pumpstrom -> NPRO-Frequenz



## Frequenzrauschen im Current Lock am NPRO

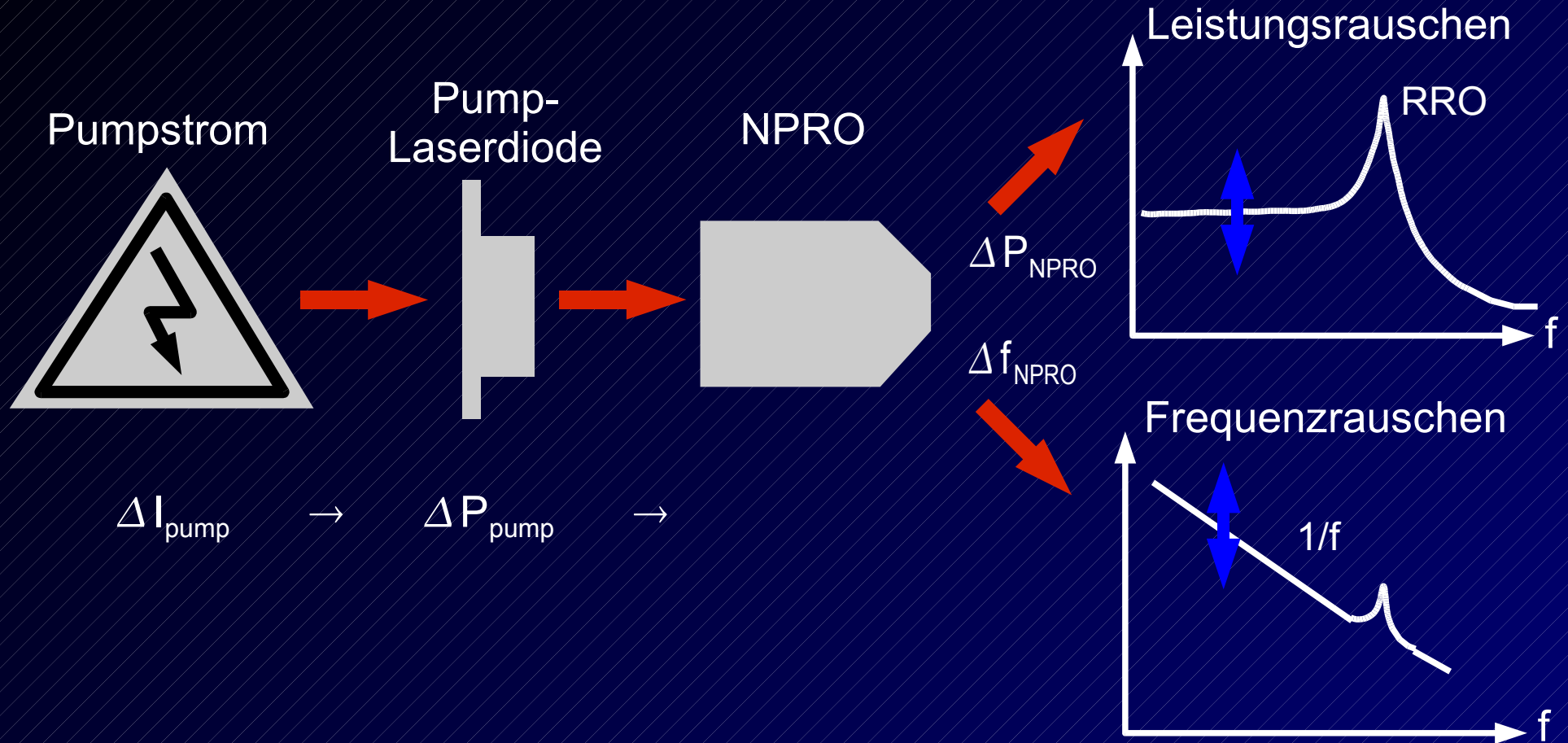


## Leistungsrauschen im Current Lock am NPRO



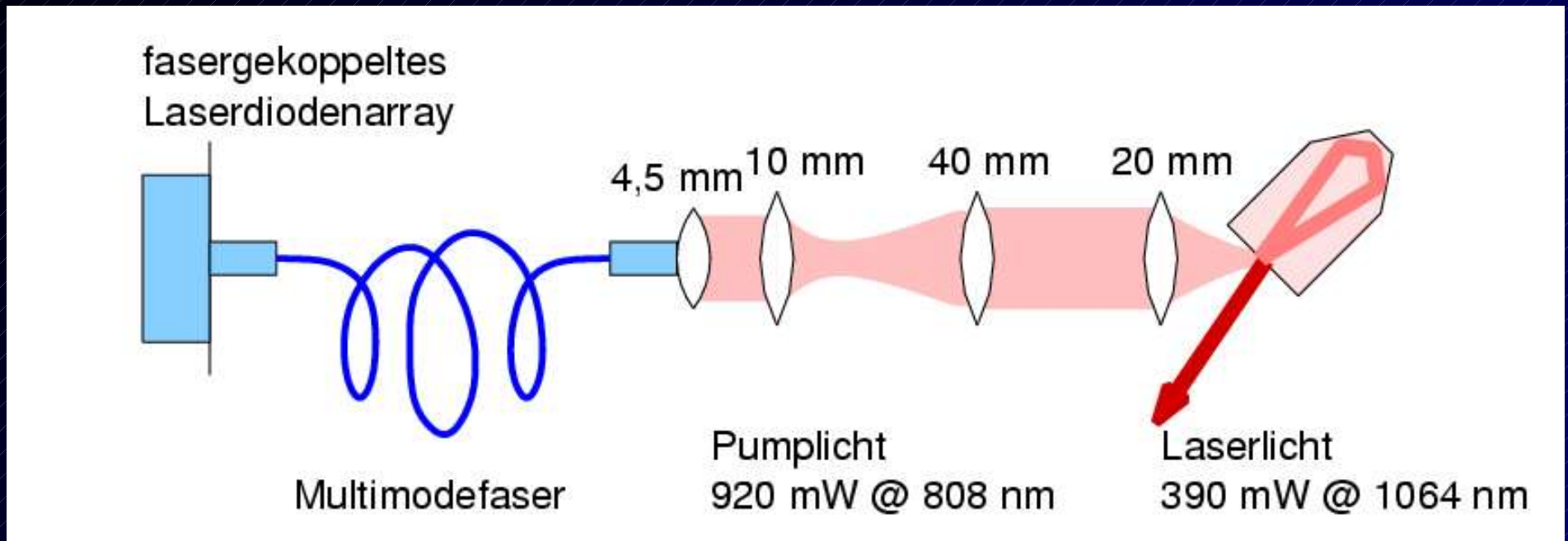


# Wirkungsweise des Current Lock



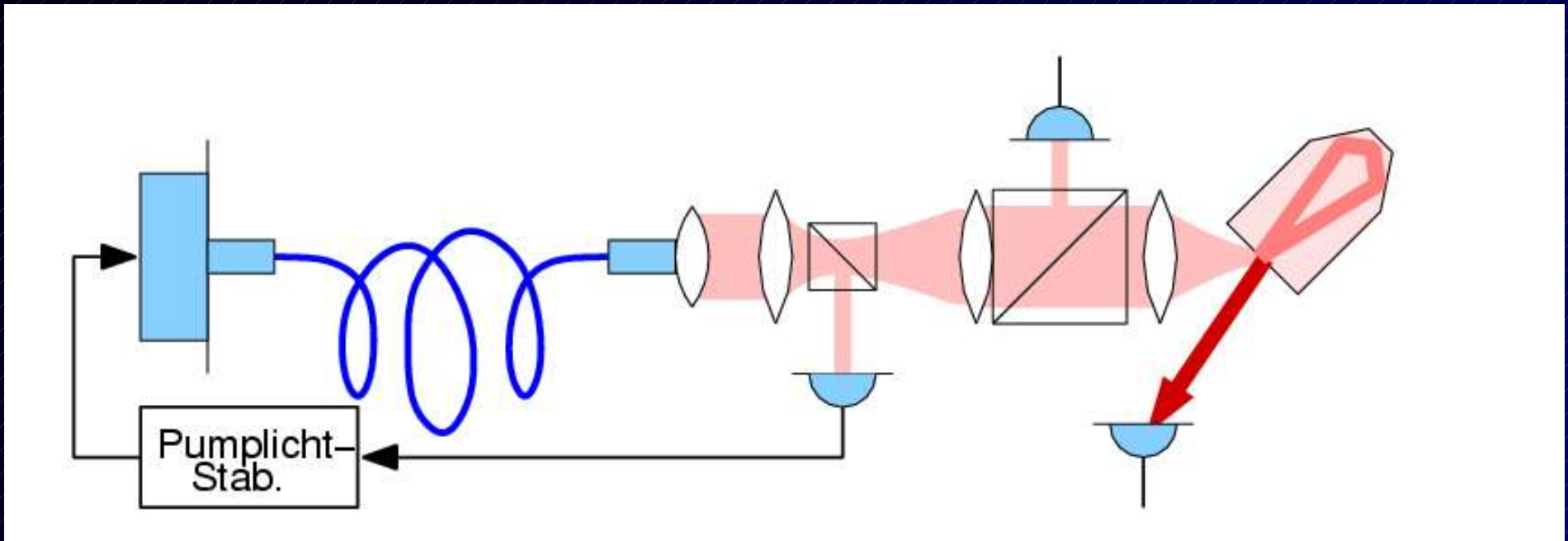


# Multi-mode laserdiodenarray-gepumpter NPRO



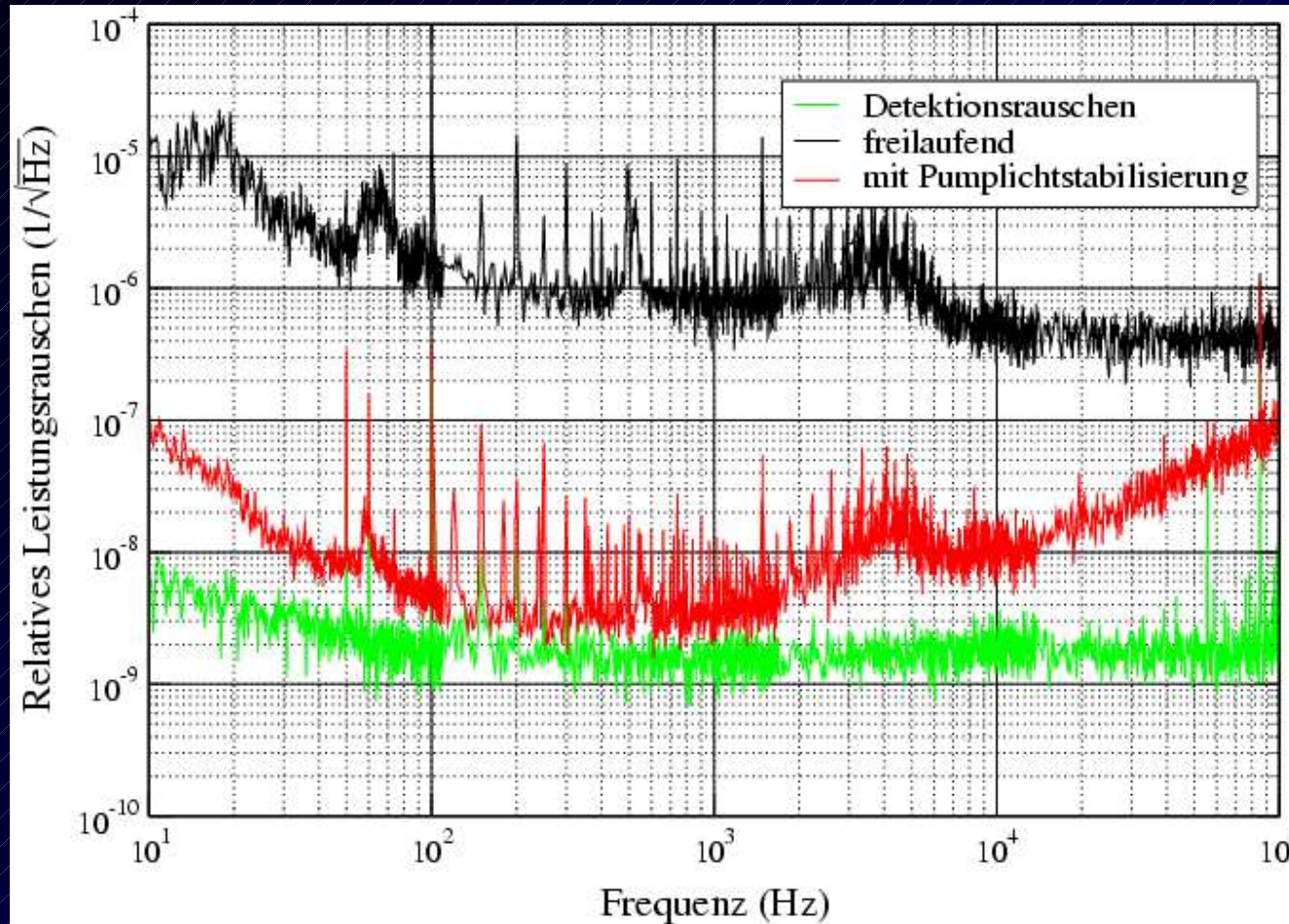


# Schema der Pumplichtstabilisierung am multi-mode laserdiodenarray-gepumpten NPRO



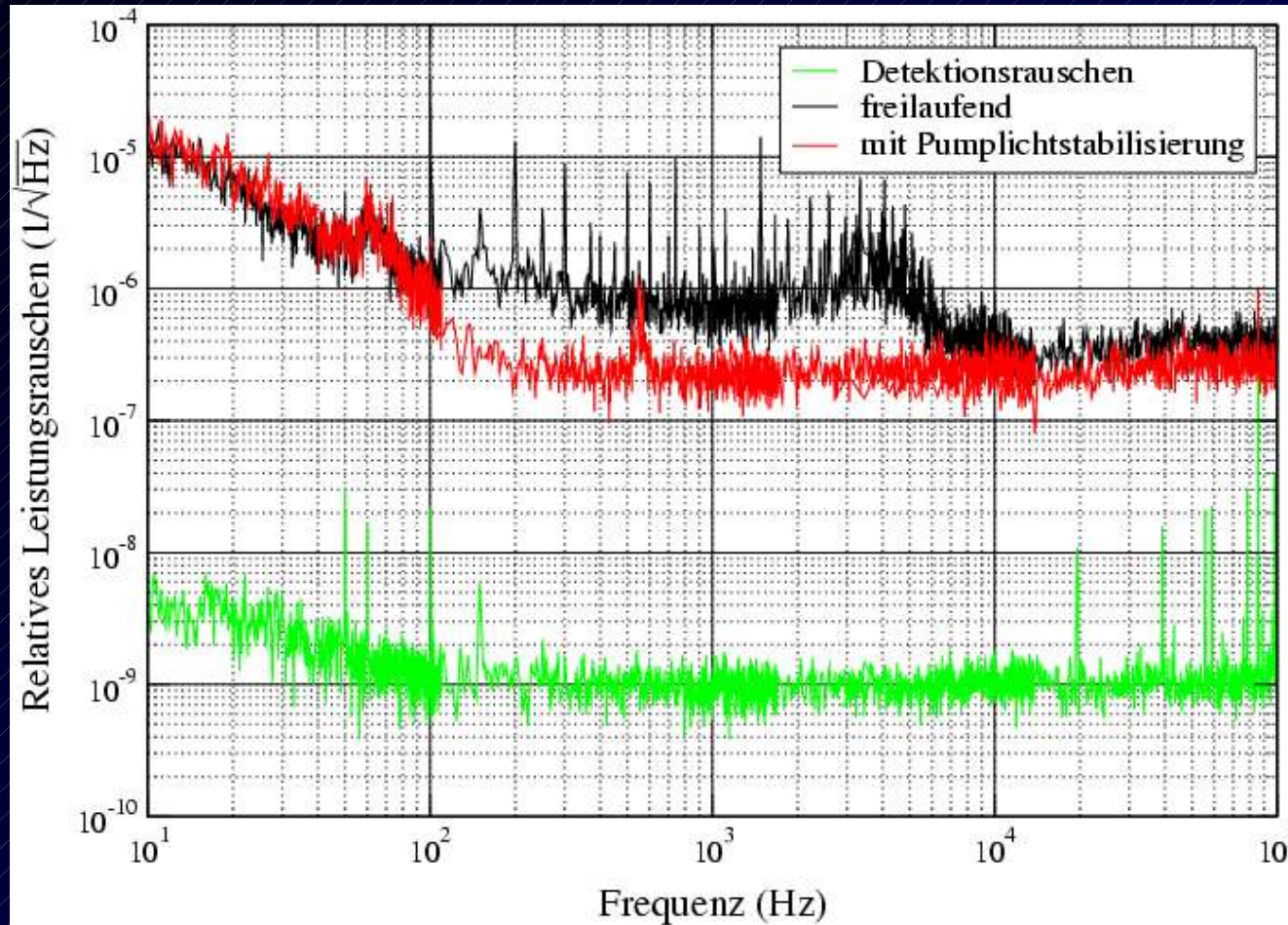


# Pumplichtstabilisierung: Leistungsrauschen des Laserdiodenarrays in loop





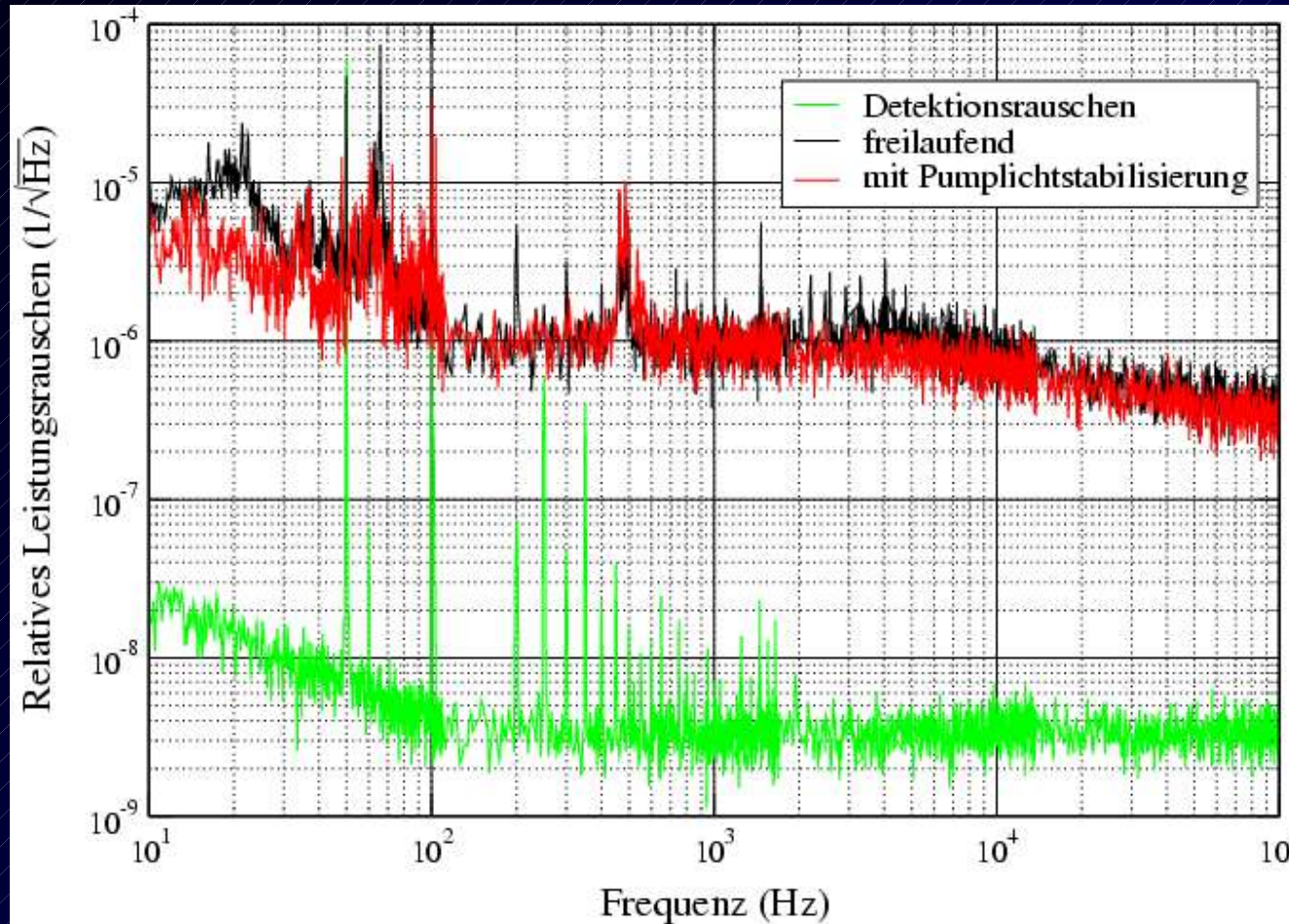
# Pumplichtstabilisierung: Leistungsrauschen des Laserdiodenarrays out of loop







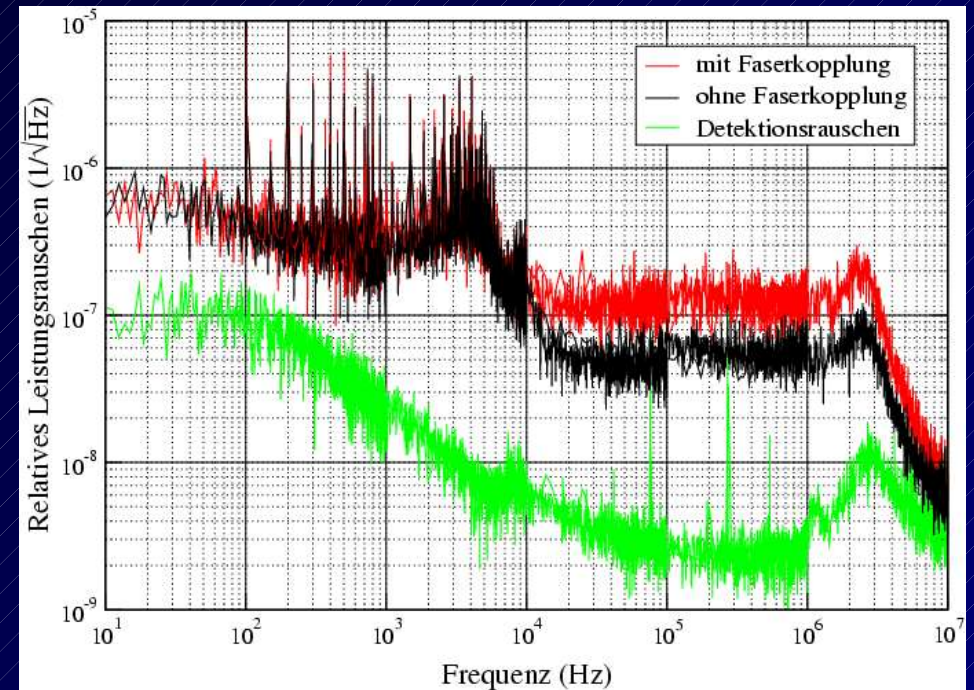
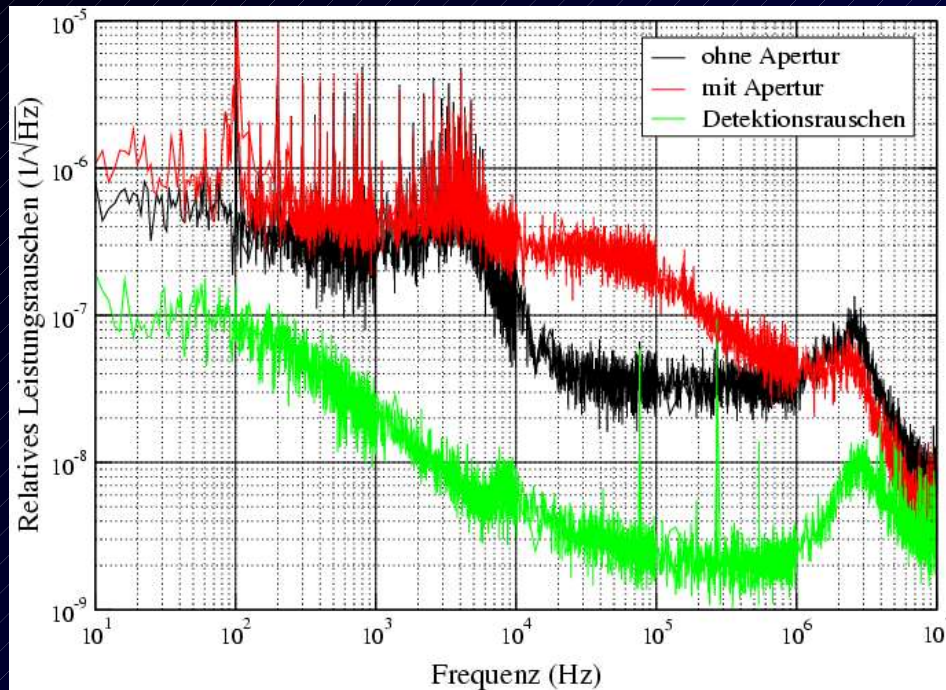
# Pumplichtstabilisierung: Leistungsrauschen des NPRO





# Résumé: Pumplichtstabilisierung des multi-mode laserdioden-gepumpten NPRO

Stabilisierung  $\Delta P_{\text{Pump}} \neq$  Reduktion  $\Delta P_{\text{NPRO}}$  wg.  $\rightarrow$  Aperturereffekt!

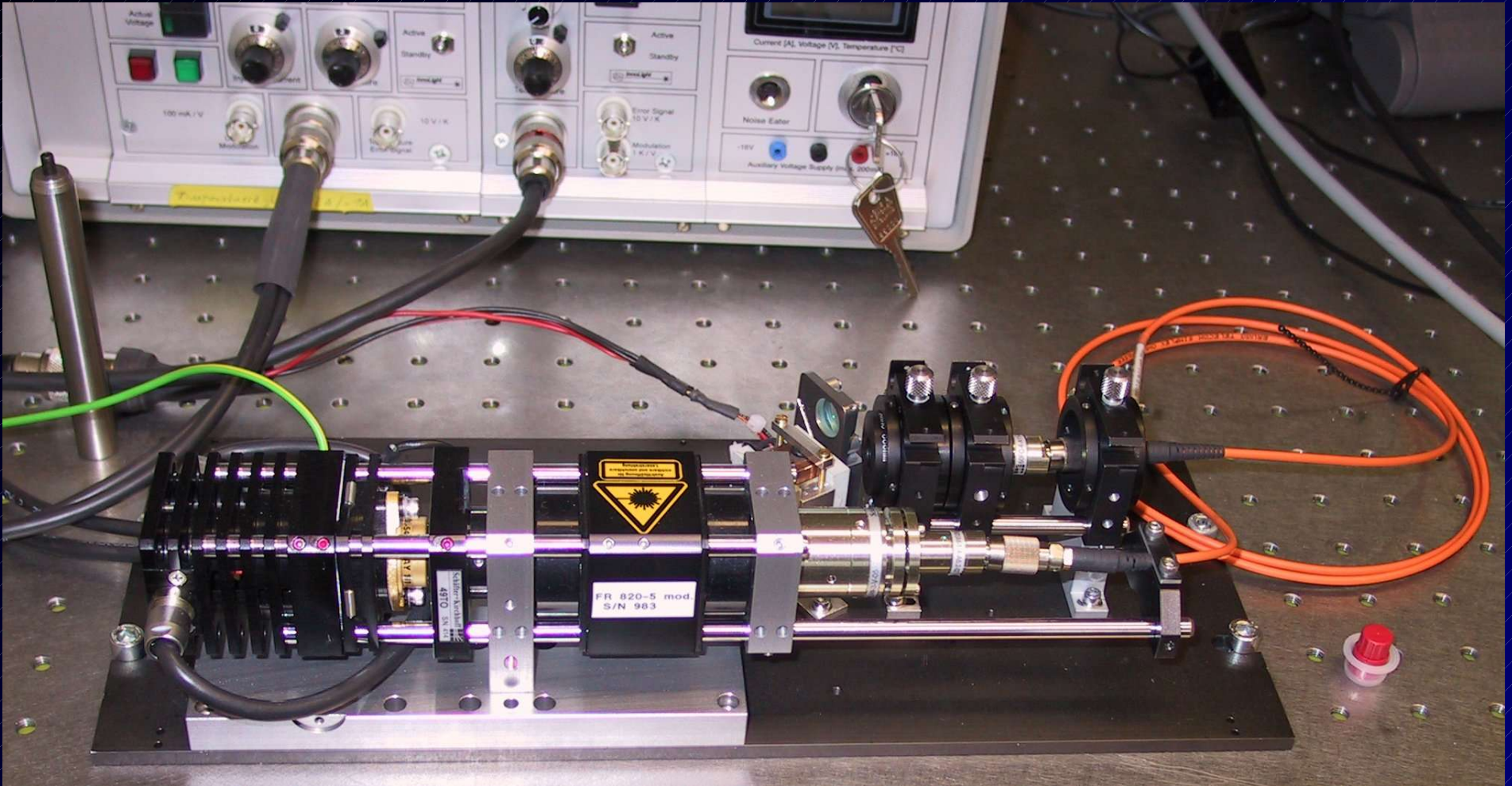


Simultane Stabilisierung



Single-mode gepumpter NPRO  
schematischer Aufbau

# Single-mode laserdioden-gepumpter NPRO



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## Experimentelle Pfade: Pumplichtstabilisierung ↔ Current Lock

Detektion und  
**Stabilisierung der  
Pumpleistung**  
(Rückkopplung auf  
Pumpstrom)



Reduktion des **NPRO-  
Leistungsrauschens?**



Reduktion des **NPRO-  
Frequenzrauschens?!?**

Detektion und  
**Stabilisierung der  
NPRO-Frequenz**  
(Rückkopplung auf  
Pumpstrom)



Reduktion des **NPRO-  
Frequenzrauschens**



Reduktion des **NPRO-  
Leistungsrauschens?!?**





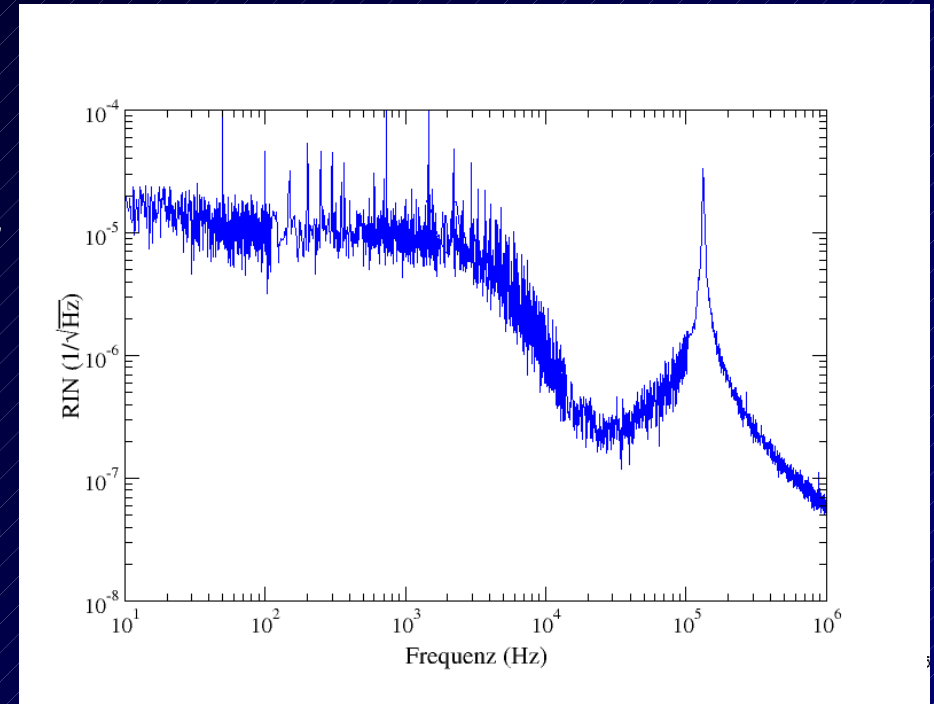
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→ Wie stark sind beide Prozesse korreliert?!?