EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

FACULTY OF
SCIENCE

**Kepler Center for Astro and Particle Physics**

# Disc Positioning Measurement for MADMAX

MADMAX Workshop Hamburg, October 18, 2017

**Christian Strandhagen**

# MADMAX Position Measurement

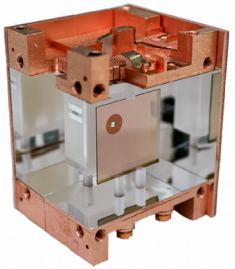
## Who are we?

Josef
Jochum

Christian
Strandhagen

## What do we do?

**CRESST**
(WIMP dark matter)



**GERDA**
(0νββ decay)


ECHO
(neutrino mass)


EUSO
(UHE cosmic rays)

# MADMAX Position Measurement

## CRESST – search for WIMP dark matter

- design and construction of muon veto system
- upgrade of SQUID readout system
- production of transition edge sensors
- data analysis and background simulations

# MADMAX Position Measurement

## GERDA – search for neutrinoless double beta decay

- design and construction of muon veto system
- characterization of germanium detectors
- data analysis and background simulations

# MADMAX Position Measurement

## What do we plan to do for MADMAX?

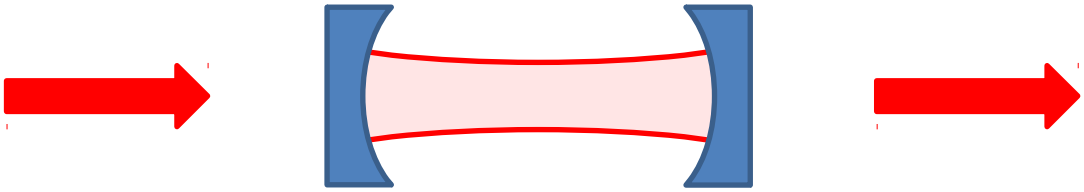
- provide a system based on laser interferometers to measure the positions of the discs with <10 µm accuracy
- design and construction will be done by quantum optics group in Tübingen via spin-off company (HighFinesse)

## Goals:

- learn about mechanical stability of the setup
- learn about influence of position changes on the boost curve
- assess if such a system is needed for the full MADMAX setup

# MADMAX Position Measurement

## Basic Concept – Optical Cavity



- consists of two semi-transparent mirrors (T ~ 1% ... 10 ppm)
- light field is solution of Paraxial Helmholtz equation

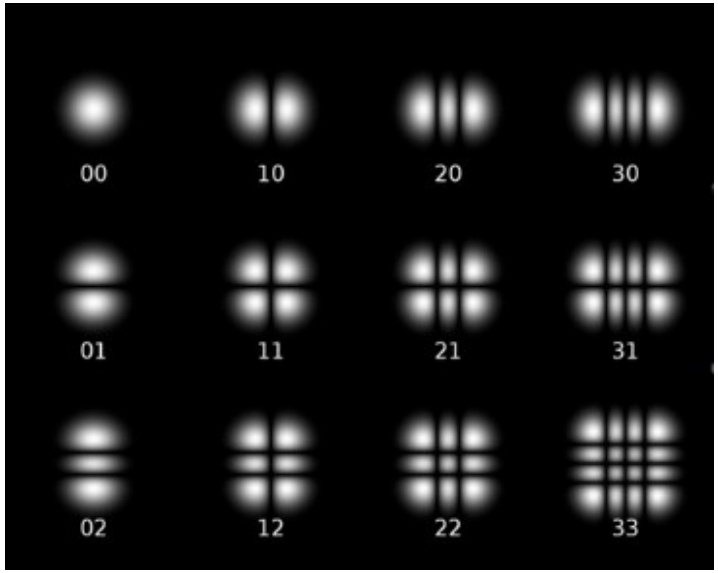
$$\left(\partial_{xx}^2+\partial_{yy}^2+2ik\,\partial_z\right)E(x,y,z)=0$$

=> discrete transverse modes with discrete allowed frequencies

# MADMAX Position Measurement

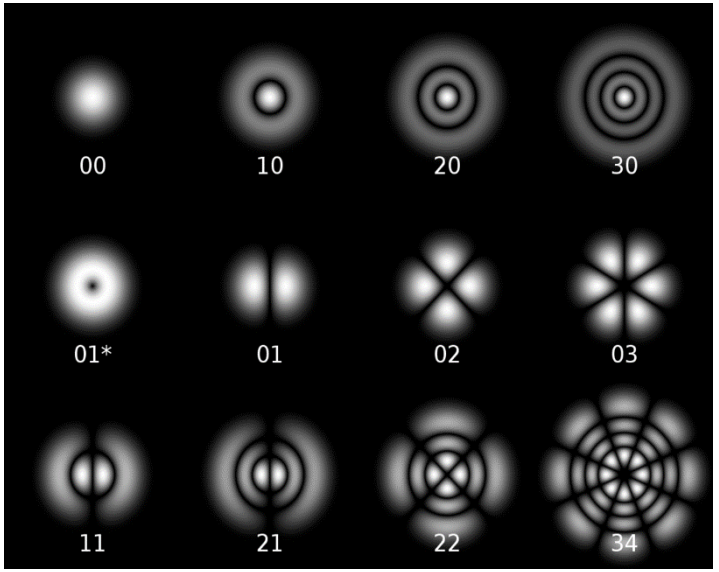
## Optical Cavity – Light Modes

rectangular geometry




Hermite-Gaussian

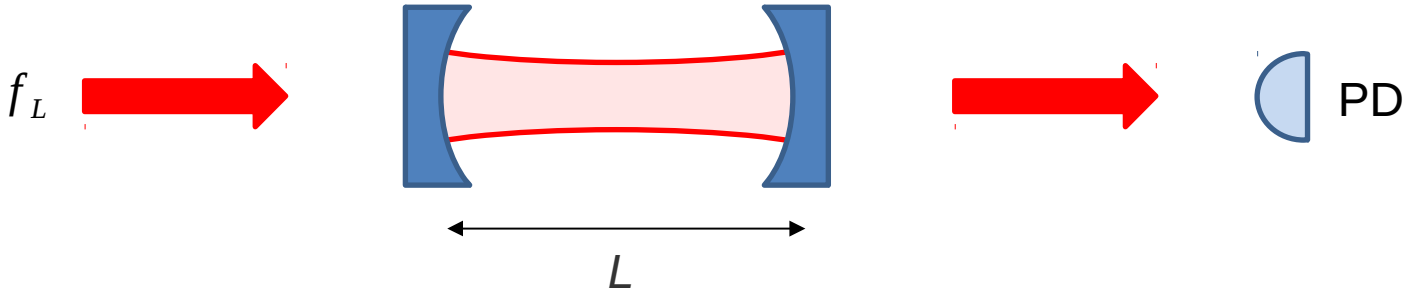
cylindrical geometry

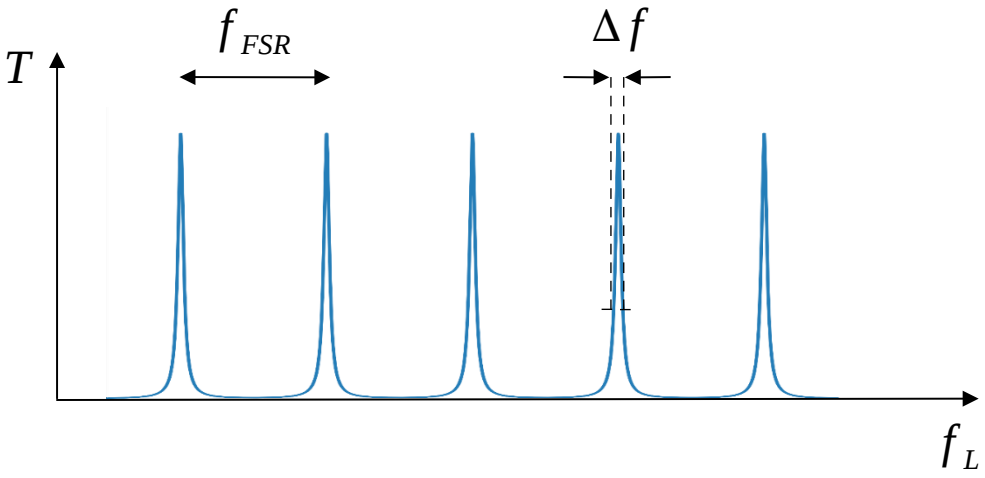



Laguerre-Gaussian

# MADMAX Position Measurement

## Measuring Length of Cavity



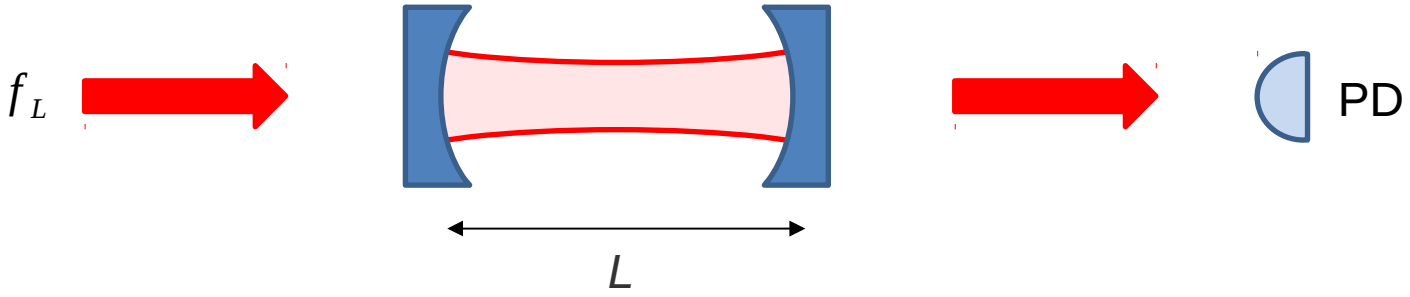

free spectral range $f_{FSR} = \frac{c}{2L}$

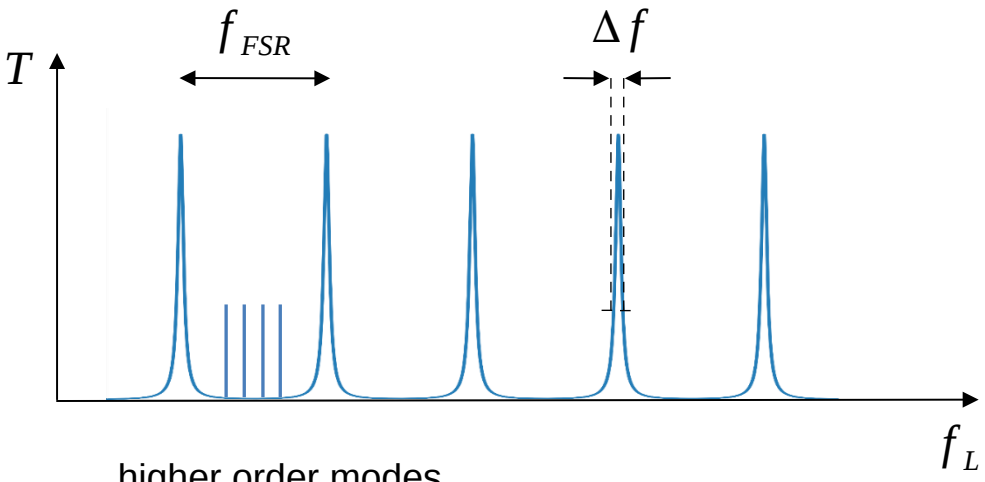
linewidth $\Delta f = f_{FSR} / F$

finesse $F = \frac{\pi \sqrt{R}}{1-R}$

# MADMAX Position Measurement

## Measuring Length of Cavity




higher order modes

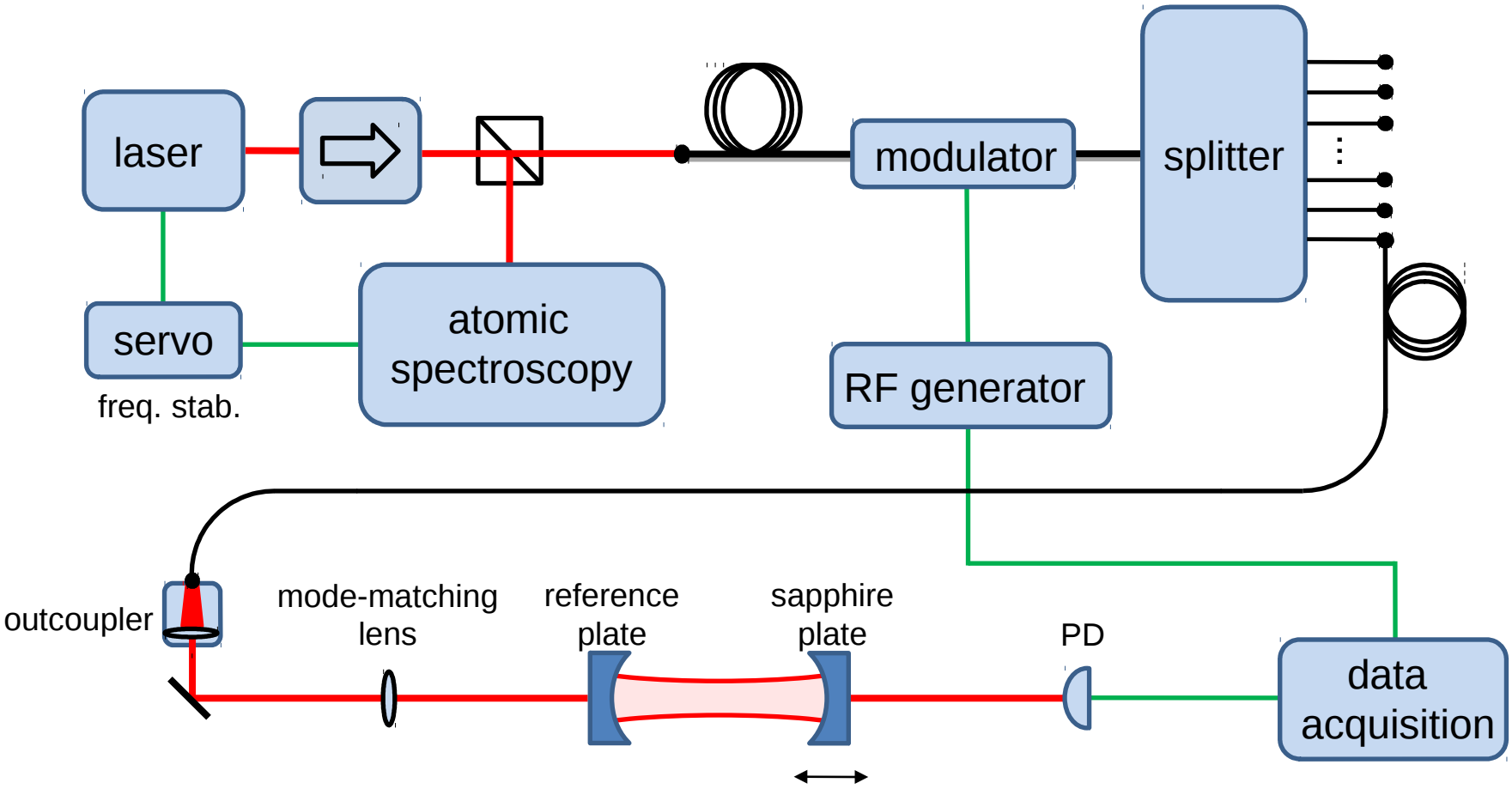
free spectral range $f_{FSR} = \frac{c}{2L}$

linewidth $\Delta f = f_{FSR} / F$

finesse $F = \frac{\pi \sqrt{R}}{1-R}$

# MADMAX Position Measurement

## Position measurement system



# MADMAX Position Measurement

## Challenges and Requirements

- how to integrate interferometers in MADMAX setup
  - attachment of mirrors to plates
  - positioning of reference plate
  - where to put photo detectors
- mechanical stability of the setup
  - tilting/rotation of discs
  - vibrations
- ambient conditions
  - temperature fluctuations
  - magnetic field

# MADMAX Position Measurement

## Work Plan

- figure out mechanical issues with a small scale setup provided by MPI group — **mid 2018**
- integrate several interferometers into existing 20 disc setup at MPI — **end 2018**

based on knowledge
gained from prototypes

- design and build system for phase 1 of MADMAX — **> 2019**

# MADMAX Position Measurement

Thank you.

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