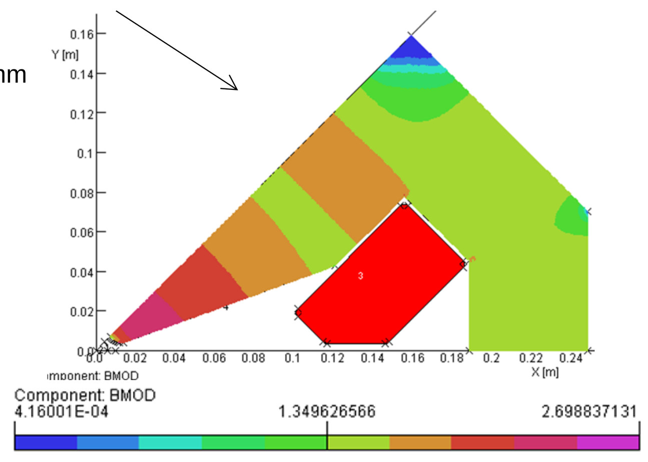
Research and Developement PETRA IV Magnets, Girders and Vibrations.

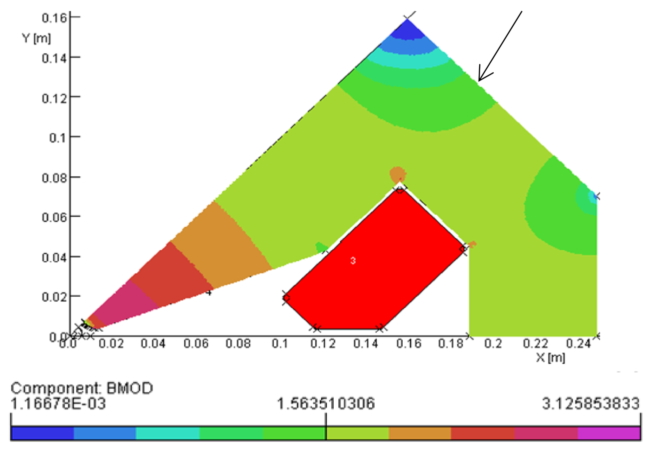
S. Andresen, M. Körfer, B. Krause, N. Meyners, A. Petrov, M. Thede

High gradient quadrupole calculations

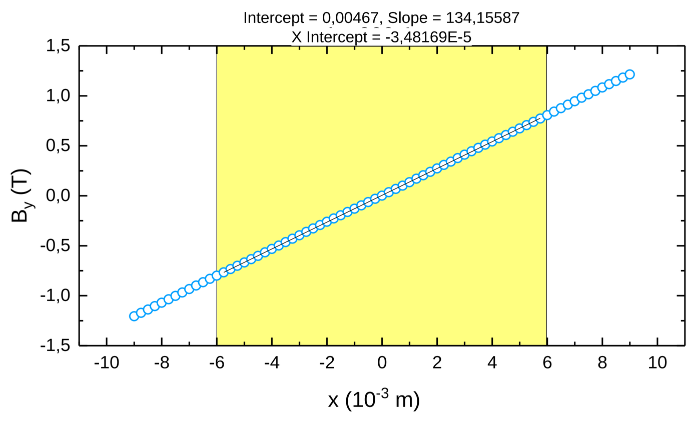
Material	HERA Steel	PowerCore 1200	PowerCore 1400	PowerCore H125-35	PowerCore H110-30	Vacoflux 50 (Pole)	Vacoflux 27
Gradient [T/m]	132	122	133	123	123	145	155
Comments	Similar to ARMCO	Standard product	New product	good axis stability	good axis stability	Very expensive 100 €/kg	new product, expensive

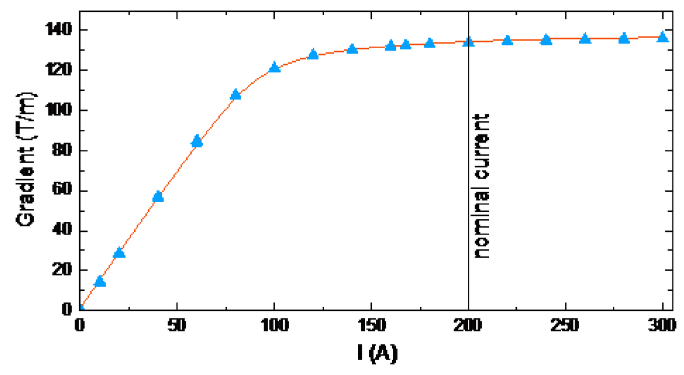
Aperture radius: 10 mm





High gradient quadrupole measurements

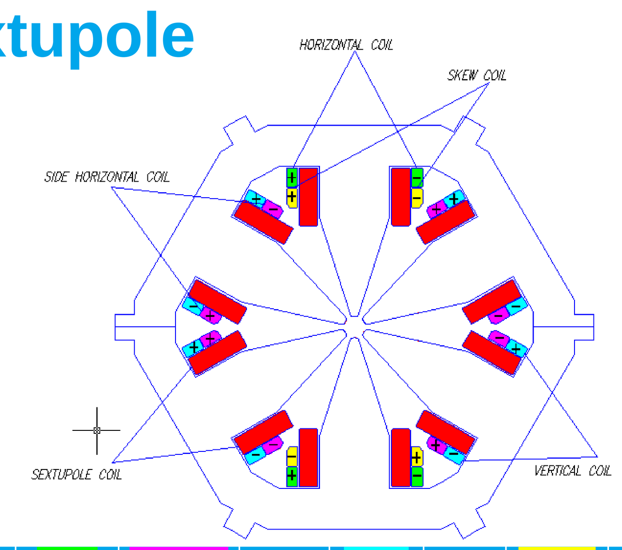




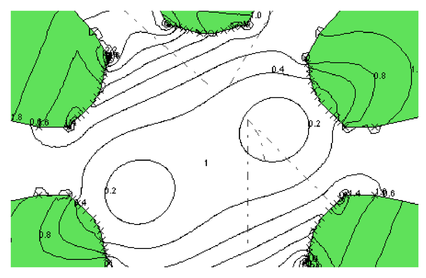
Effective gradient: 136 T/m

Required gradient: 130 T/m

Combined function sextupole



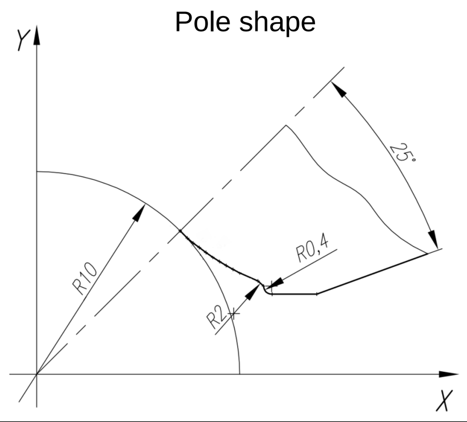
	AWsext (one coil) kA	AWhor (one coil) kA	AWhorside (one coil) kA	By(0,0) T	AWvert (one coil) kA	Bx(0,0) T	AWskew (one coil) kA	$1/2d^2B/dr^2$ T/m²
1	5.4	0.0	0	0		0	0	3365.5
2	0	-3.0	0	0.1333	0	0	0	0
3	5.4	-3.0	0	0.0977	0	0	0	3147.2
4	5.4	-3.0	-3.0	0.1118	0	0	0	3266.6
5	5.4	-3.0	-3.0*0.9	0.11225	0	0	0	3261.4
6	5.4	-3.0	-3.0*0.8	0.1122	0	0	0	3255.5
7	5.4	-3.0	-3*0.7	0.11167	0	0	0	3249.1
8	5.4	0	0	0.0177	0	0.0	-3	G=2.6T/m 3254.6

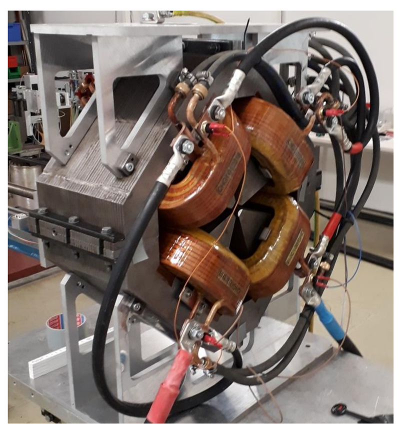


Aperture radius: 16.5 mm

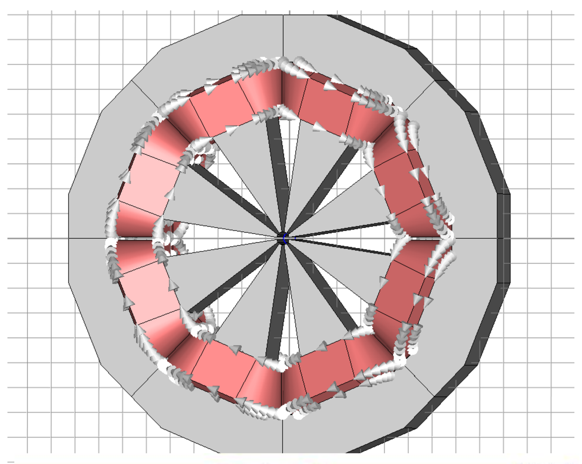
All coils powered

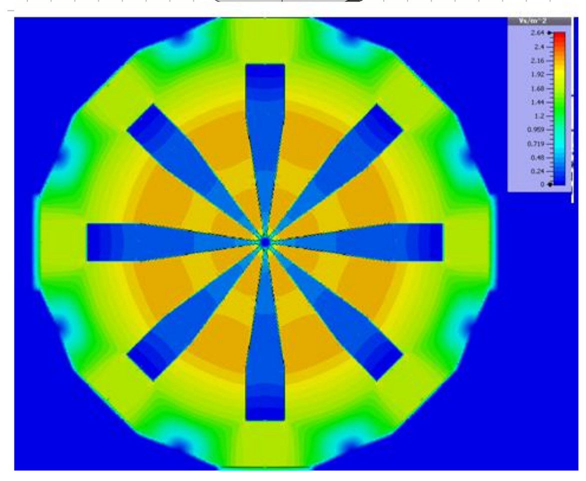
High gradient prototype quadrupole HERA steel





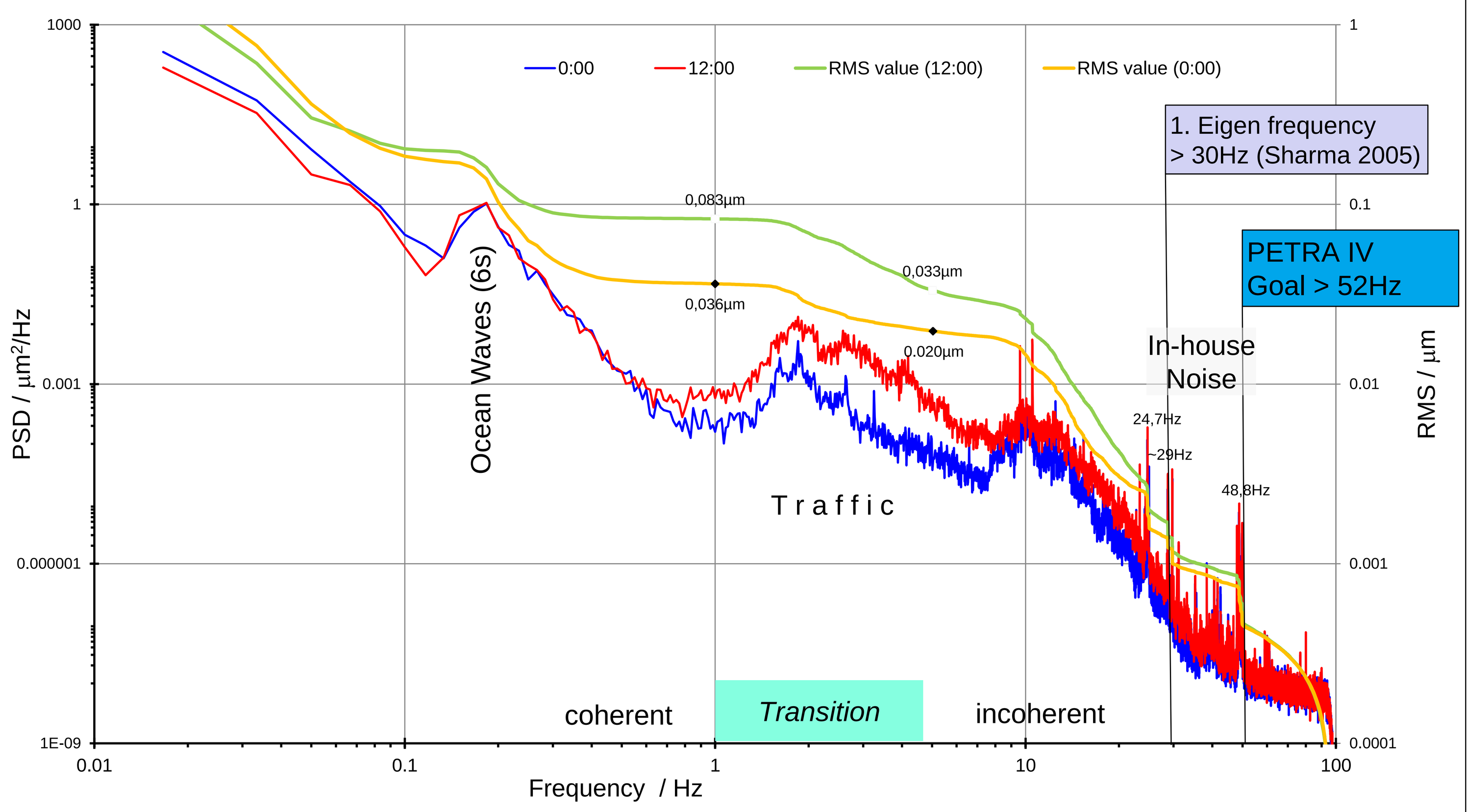
Octupole calculations





Outer diameter: 710 mm
Bore radius:13 mm
Iron length: 90 mm
Calculated G: 339120 T/m³
Required G: 300000 T/m³
Min.gap between poles: 4.6 mm

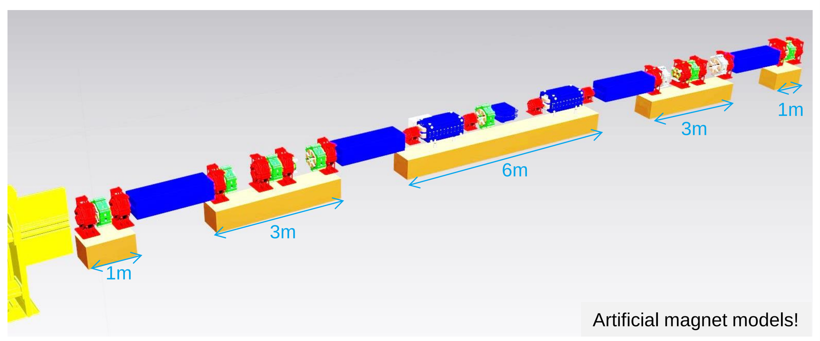
Ground vibration at DESY



Measurement of the ground vibration in the PETRA III experimental hall „Paul P. Ewald" which is close to the main road ("Luruper Chaussee") on Nov. 14; 2016 at noon and midnight
Day and night difference mainly due to road traffice can be clearly seen

➔ **Goal for the PETRA IV girder design study: 1st eigenfrequency > 52 Hz**

PETRA IV girder length (26.2 m-lattice structure)



For girder design study:

- 26.2 m-lattice as baseline
- Dipole magnets on separate supports
- All multipole magnets on common girder

➔ **For 26.2 m-lattice structure**

- **Girder lengths: 6 m, 3 m and 1 m**

Open issues:

- **Remote controlled supports**
- **Girder eigenfrequencies and pedestals**
- **Magnets on mover system**

Different approaches to the PETRA IV girder design

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

PROJECT

Research project

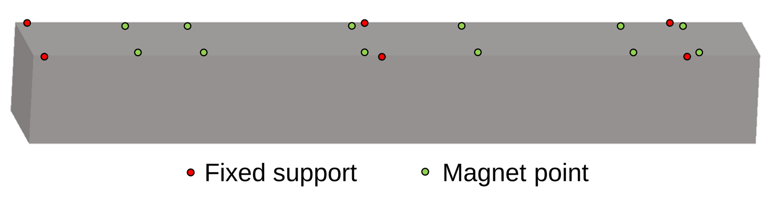
The project is conducted in cooperation with the research section "Bionic lightweight design and functional morphology" of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), which has a high expertise in bionic lightweight design and structural optimization.

Project goals

- Development of different designs for the PETRA IV girders with high eigenfrequencies above 52 Hz, high static stiffness and low structural mass (< 2500 kg)
- Fabrication of girder prototypes
- Prototype measurements and validation of simulations

Design space

The girder design space (grey) was based on a PETRA III girder (4.2 x 0.65 x 0.525 m). Three magnets of 1.2, 1.8 and 1.2 t mass were included each apportioned among four points. The girder bases were neglected.

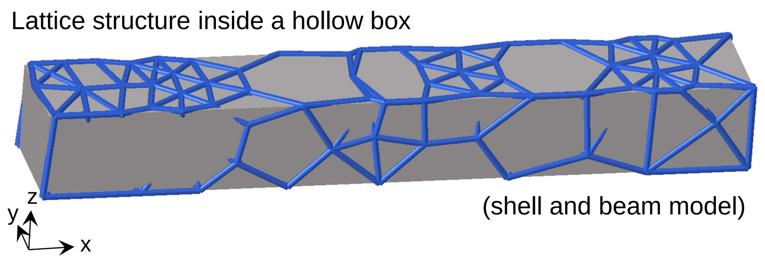


DESIGN APPROACHES

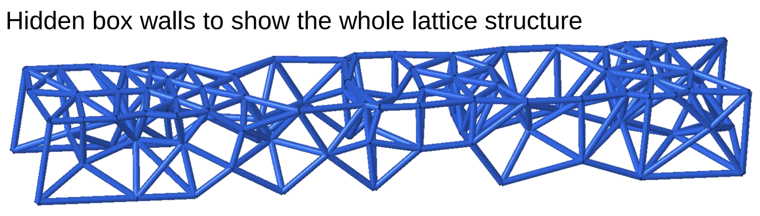
Biologically inspired lattice structures

Irregular lattice structures are widely spread in nature. The shells of marine protozoa show an enormous diversity of irregular lattice structures which are not just inspiration for lightweight designs, but also expected to positively influence the vibration characteristics.

Lattice structure inside a hollow box



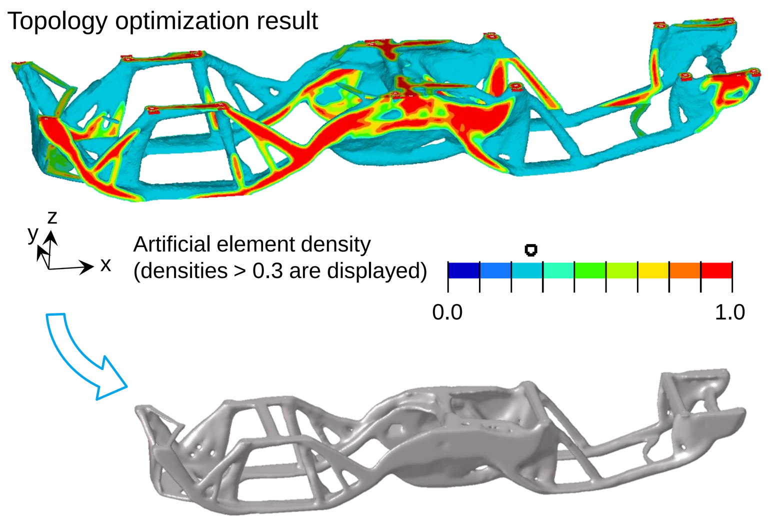
Hidden box walls to show the whole lattice structure



Topology optimization

Topology optimizations are used to identify an optimal design of a structure within a specified design space. The resulting structure meets the defined goals at lowest possible mass.

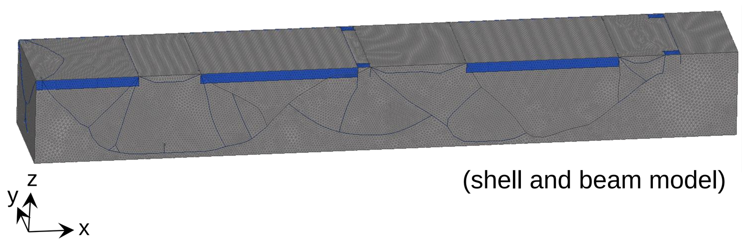
Topology optimization result



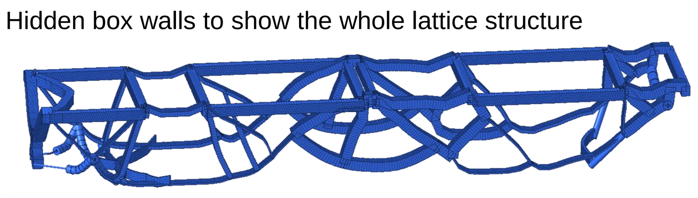
Structural optimizations based on evolutionary strategy

Starting with the topology optimization result, further optimizations aiming at the defined goals lead to structures with improved properties. The used evolutionary strategy is based on the principles of evolution involving selection, mutation and crossover.

Inner stiffening structures (ribs and beams) of a hollow box

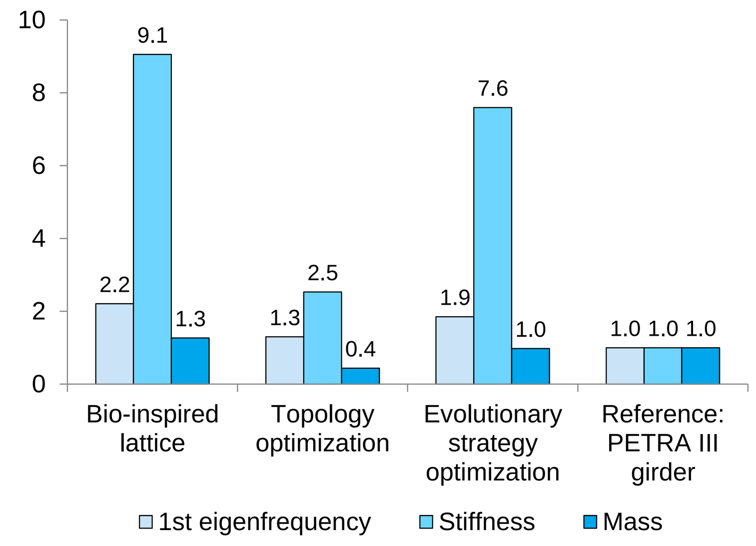


Hidden box walls to show the whole lattice structure



Comparing the different approaches

The figure stated below summarizes the 1st eigenfrequency, stiffness and mass of the three structures. The values are normalized by the reference values obtained for the PETRA III girder and displayed above each bar.



Andresen, S. (2018): "Optimizing the PETRA IV girder by using bio-inspired structures", in *Proc. MEDSI'18*, Paris, France.