

An Echelle Spectrograph for the Milanković Telescope (MILES)

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Rationales

Since the 1.5 m class Milanković telescope will be operated by the Astronomical Observatory of Belgrade, it will guarantee long and secured access for observers, which is ideal for dedicated **monitoring programmes** of variable phenomena.

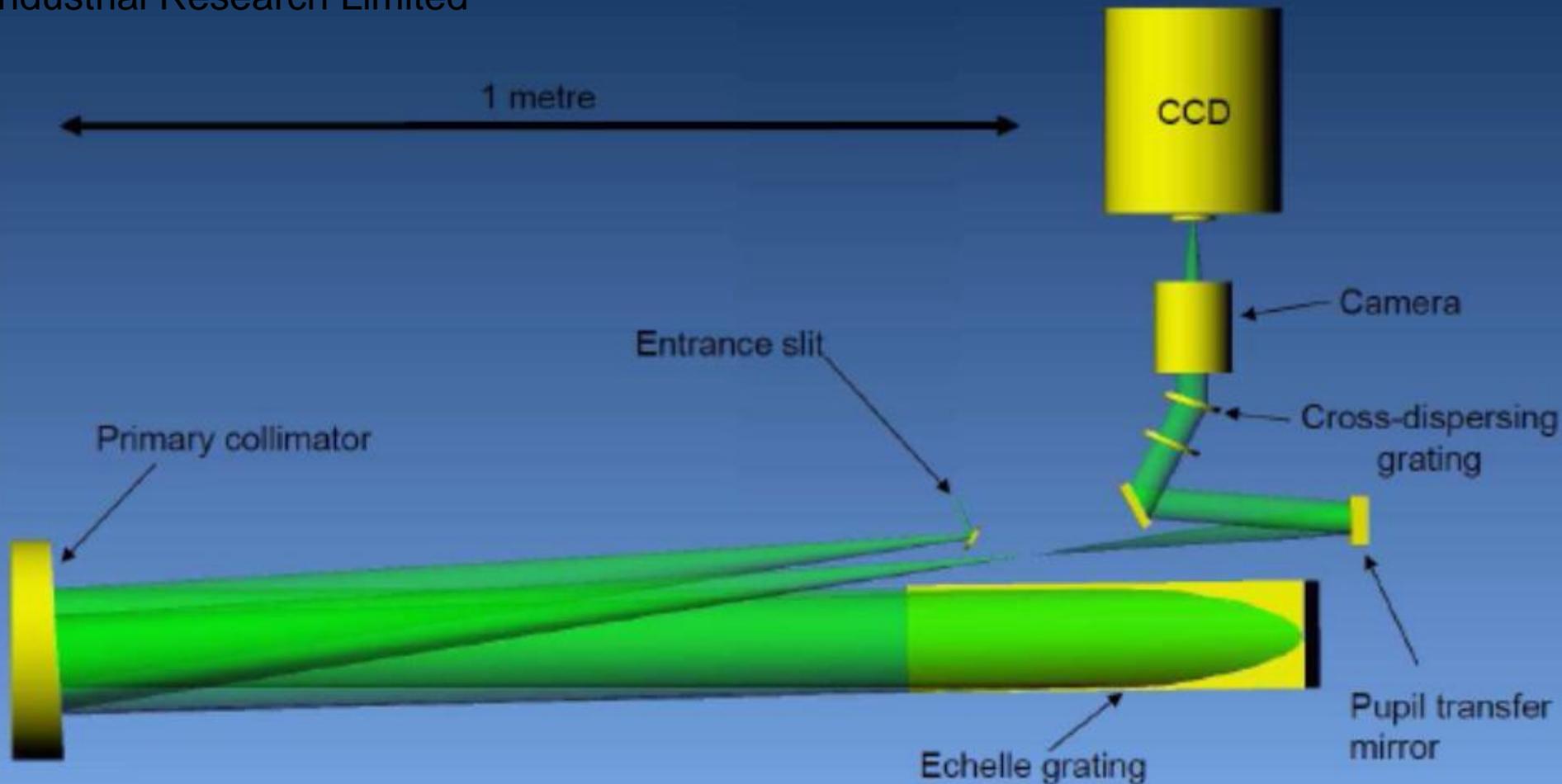
Telescopes of **~1.5 m objective diameter** are ideal for **high spectral resolution (R~50000)** observation of celestial objects with available large grating sizes ~ 50 cm and seeing conditions (~2") at Vidojevica Astronomical Station.

Therefore we plan to use the telescope for collecting high-quality time series of high-resolution spectra.

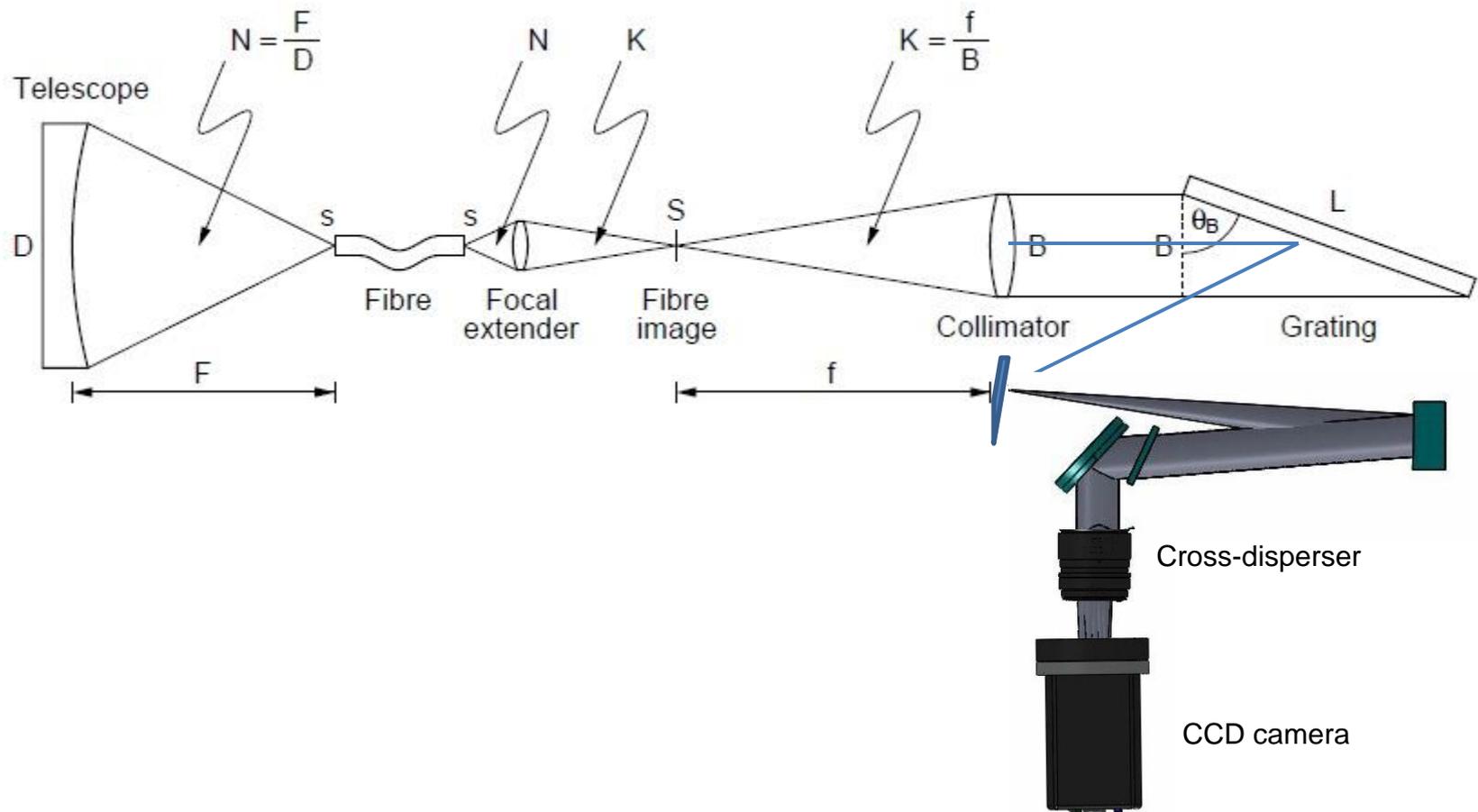
Based on our prior experiences with various spectra taken for line profile analysis of solar like stars and radial velocity measurements of close binary stars, we propose for the **MiL**ankovic telescope a high-resolution, fiber-fed , gravity-invariant , thermally-controlled **E**chelle **S**pectrograph (**MILES**) with **white pupil** optical design.

KiwiSpec spectrograph (~1100 kEU)

Industrial Research Limited



Main elements of a fiber-fed echelle spectrograph.



**Milanković Telescope will be
installed at Vidojaevica
Astronomical Station**

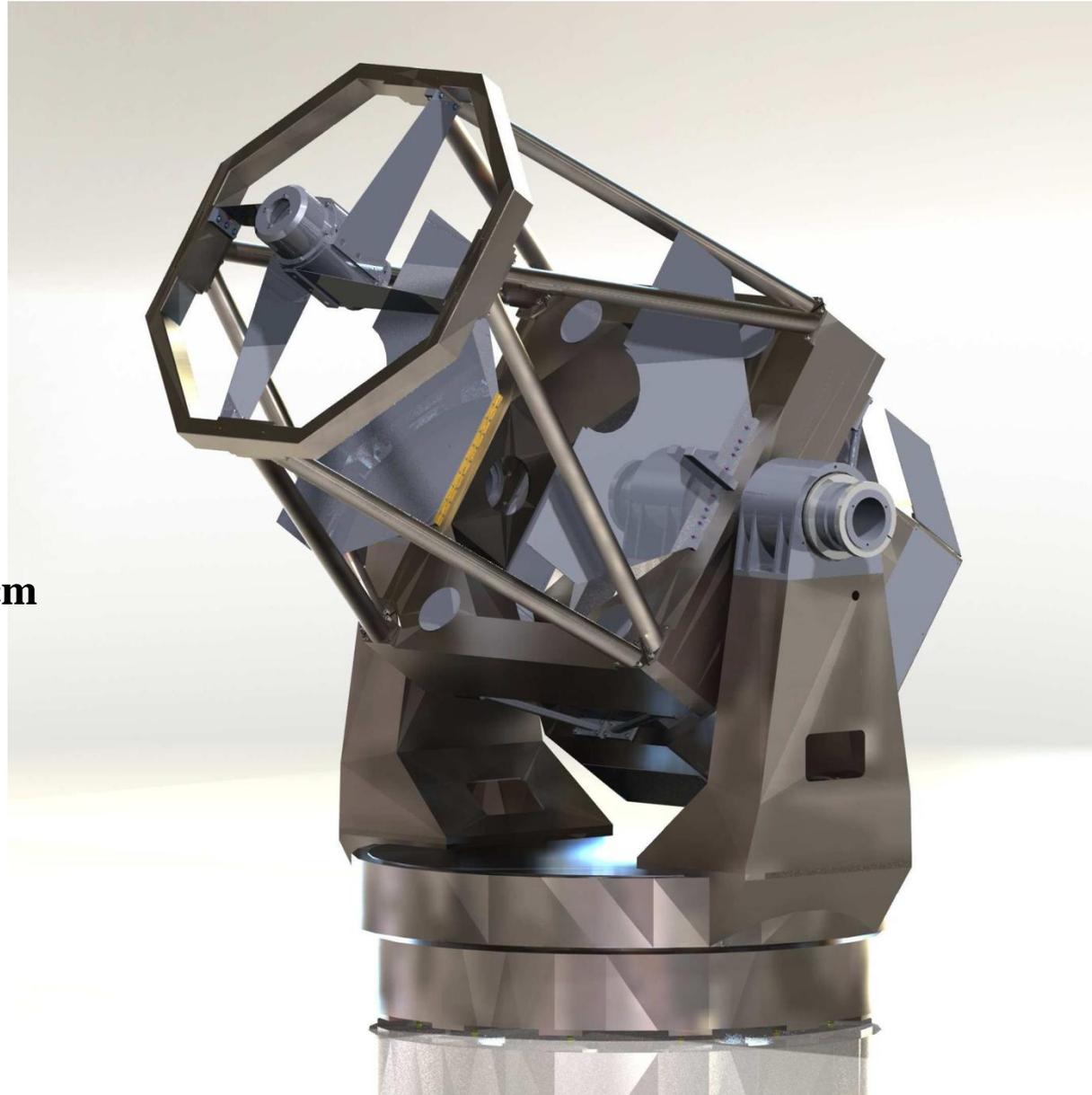
Ritchey-Chrétien or Cassegrain
optical design

Primary mirror diameter: ~150 cm

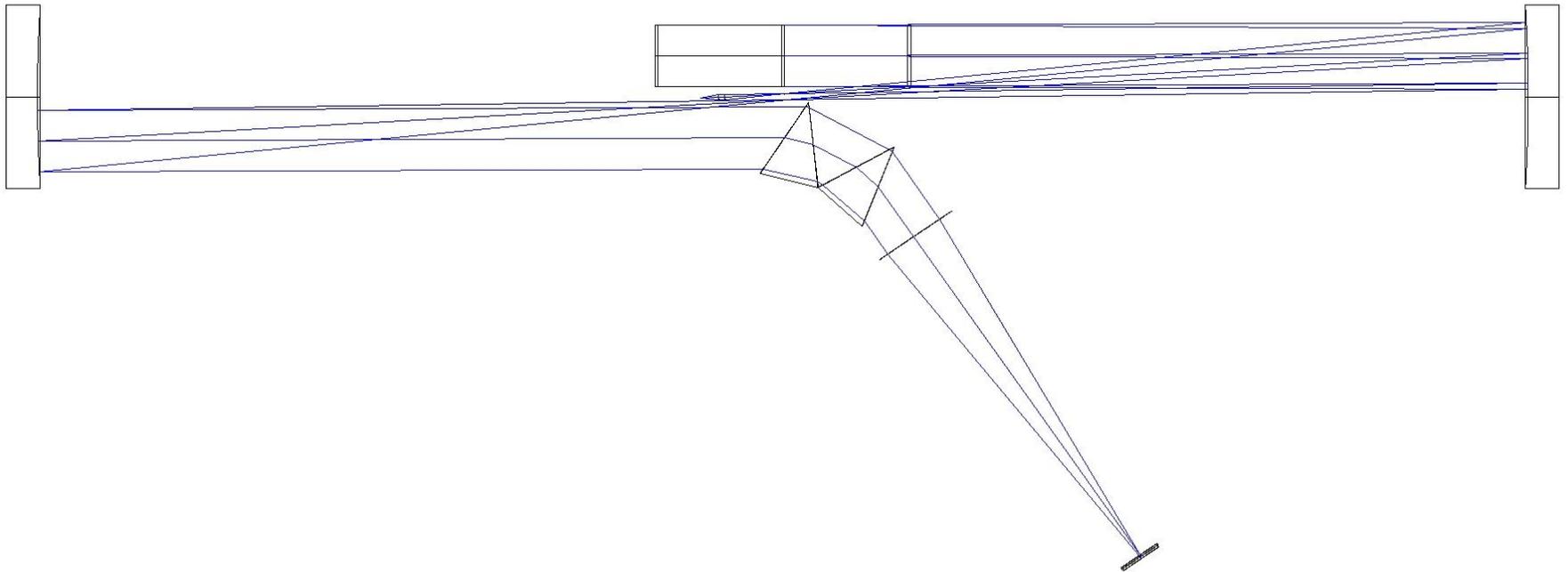
Effective optical aperture: > 135 cm

Effective system focal ratio: f/8

**Gathering power (0 mag):
~1400 photons/s/Å**



High-resolution fiber-fed echelle spectrograph – version B



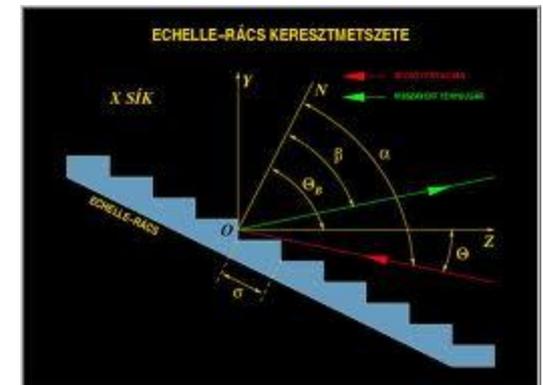
Echelle Grating

(60 kEU)



Richardson Gratings:

- **Grating Surface:** Ruled
- **Groove Frequency:** 31.6 per mm
- **Blaze Angle:** 76 degrees ($\tan \theta = 4$)
- **Groove Length:** 100 mm
- **Ruled Width:** 400 mm
- **Material:** low expansion glass
- **Coating:** aluminum





Collimator(s)

(2+2 kEU)

Orion Optics (UK):

- **Parabolic mirror(s)**
- **D=300 mm**
- **F=1200 mm**
- **F:4**
- **PV wavefront error is less 1/10PV**
- **Strehl values typically around 99%**



Cross dispersers

(2*12.5 kEU=25kEU)

Optique Fichou (France)

Two identical prisms:

Dimensions: 140x140 mm

Apex angle: 40 deg

Made of: PBL2Y glass (OHARA)

CCD detector

(155 KEU)

Spectral Instruments Inc.

www.specinst.com



1100 Series:

- Read noise 100kHz 2.1e-
- Read noise 344kHz 2.7e-
- Read noise 709kHz 5.3e-
- Read noise 1.5MHz 9.7e-
- **Dark current -90°C 0.0003e-/pixel/s**
- Full well 320ke-
- Linearity <1%, 400e- to 300ke-
- CCD Size 61.4mm x 61.4mm
- **CCD pixel size 15μm**
- **CCD chip dimension 4096(H) x 4112(V) pixels**

Camera optics (10 kEU)



- Diameter: 140 mm
- Focal length: 640 mm





Kinetic Systems, Inc.
Research grade optical table:
Length: 244 cm
Width: 122 cm

Optical table

(10 kEU)

TMC Vibration Control
Vibrational Isolation Optical Top,
Optical Table





Optical fiber

(5 kEU)

[CeramOptec](#)

$N/A=0.12$ ($=\sin(\theta)$; $\theta(0.12)=\arcsin(\theta)=6.89$ deg)

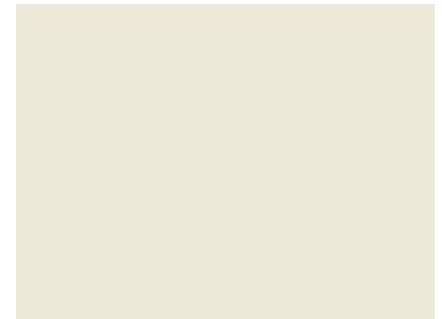
Length= ~ 20 m

Input focal ratio: $f/4$ ($f/N=2*\tan(\theta)=f/4.1$)

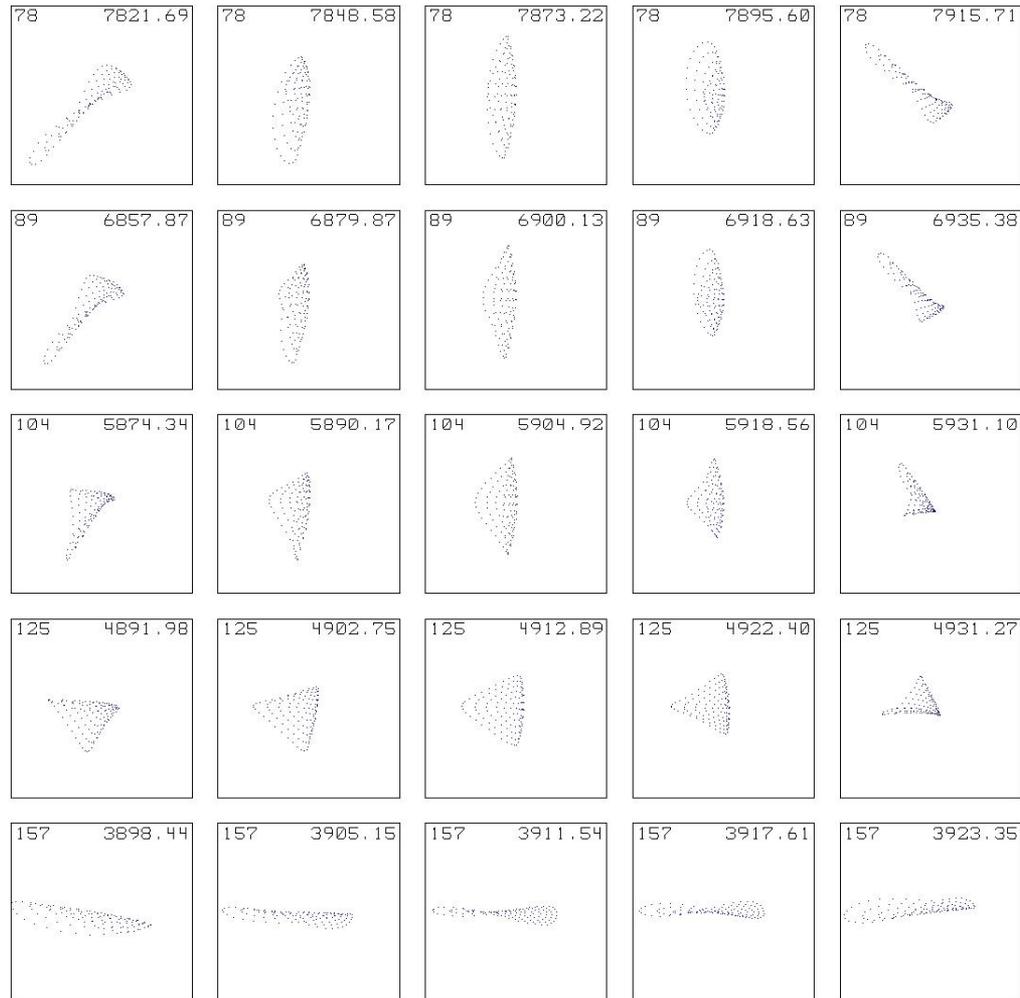
Output focal ratio: $f/3.75$

Output focal ratio converter (lens): $f/12$

Diameter of divergent beam at collimator: 10 cm



MILES spot diagrams for five representative orders (78, 89, 104, 125 and 157)
Wavelengths are indicated at right upper corner in Angstroms. Each box represents 2
× 2 pixels (30 μm)



Recapitulation

MILES main characteristics:

- White-pupil (100 mm diameter only)
- Resolving power ~ 50000
- Max. throughput $\sim 15\%$ (at 600 nm)
- Estimated cost:

(E+COLL+CROSSD+CAMLENS+CCD+OTABLE+OPFiber+Others)
(60+4+25+10+155+10+10+5)

Optical elements \sim **275kEU**

x 2

Ready-made spectrograph \sim 550kEU

Conclusion

A high resolution spectrograph (MILES) for the Milanković telescope is proposed.

The white-pupil design spectrograph gives a relatively small pupil on entrance to the cross-dispersers and cameras, resulting in a significant cost saving and complexity reduction.

The MILES spectrograph and the Kiwispec commercial spectrograph share a similar design, with very similar performances but the MILES price is 50% less than the commercial one.

END

Resolving power

$$R=2L\sin B/(sD)$$

L – echelle grating length (50 cm)

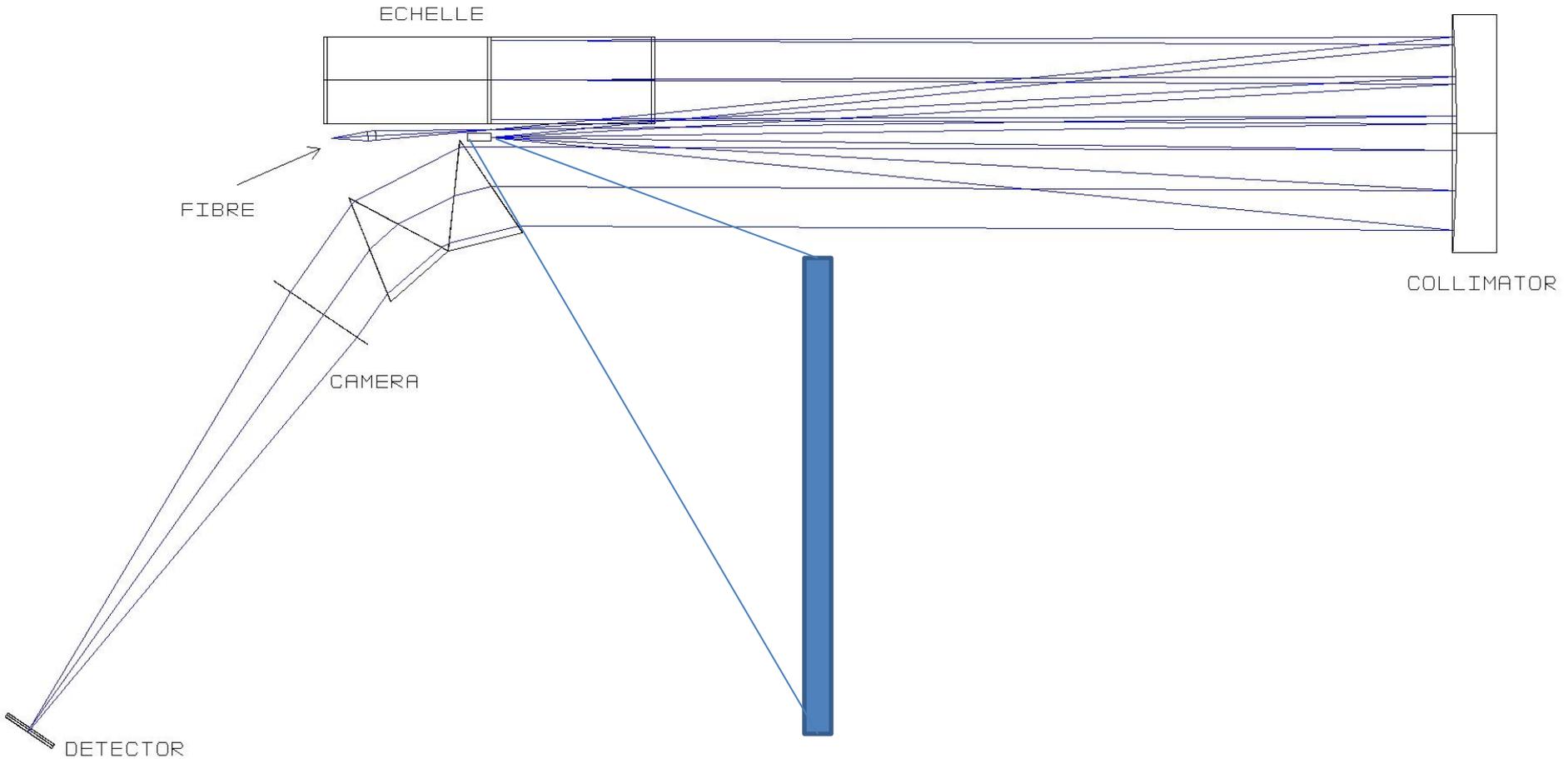
B – blaze angle (70 deg)

s – angular size of fiber entrance diameter projected onto the sky (2.5")

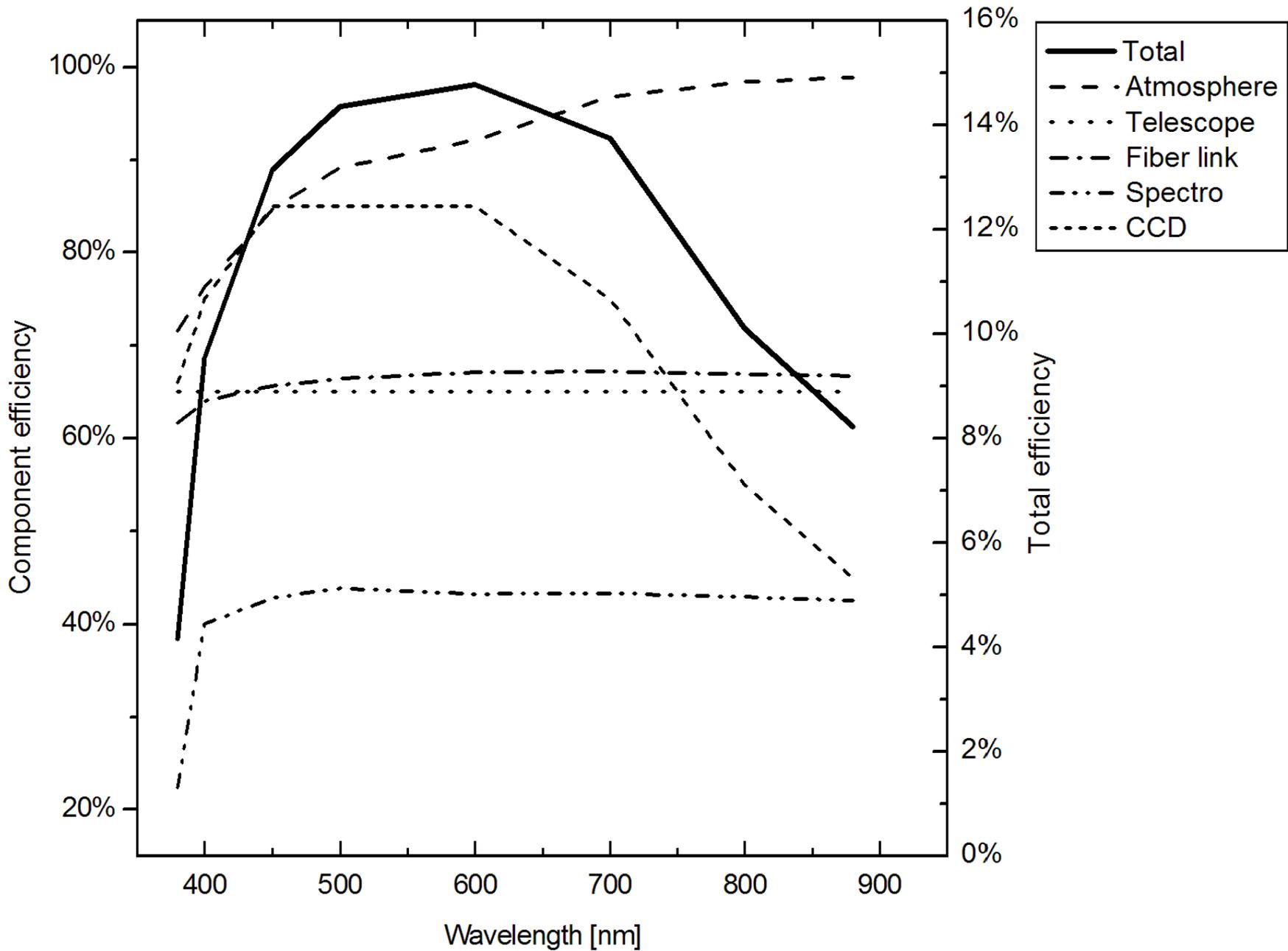
D – telescope diameter (1.5 m)

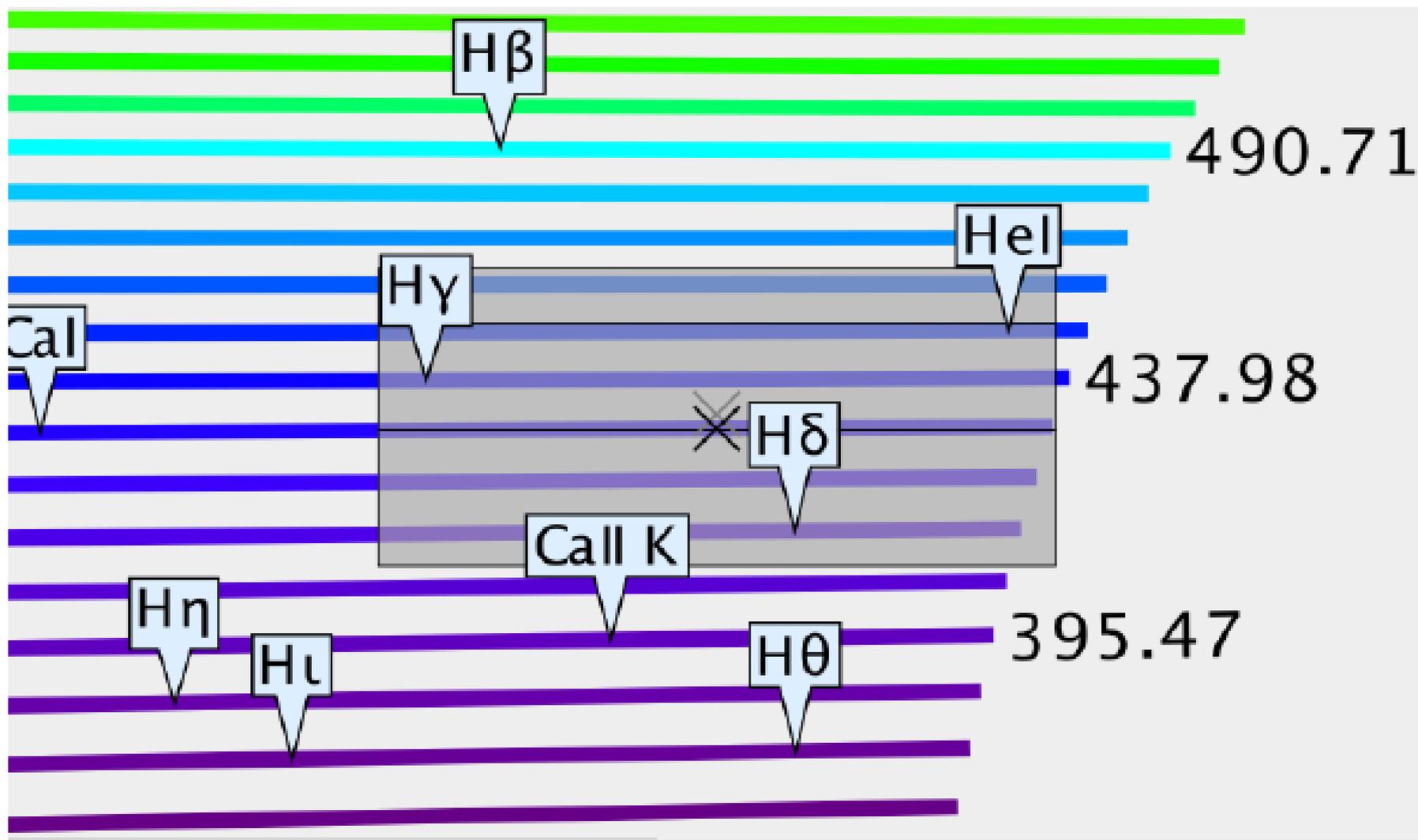
R~50000

High-resolution fiber-fed echelle spectrograph – version A

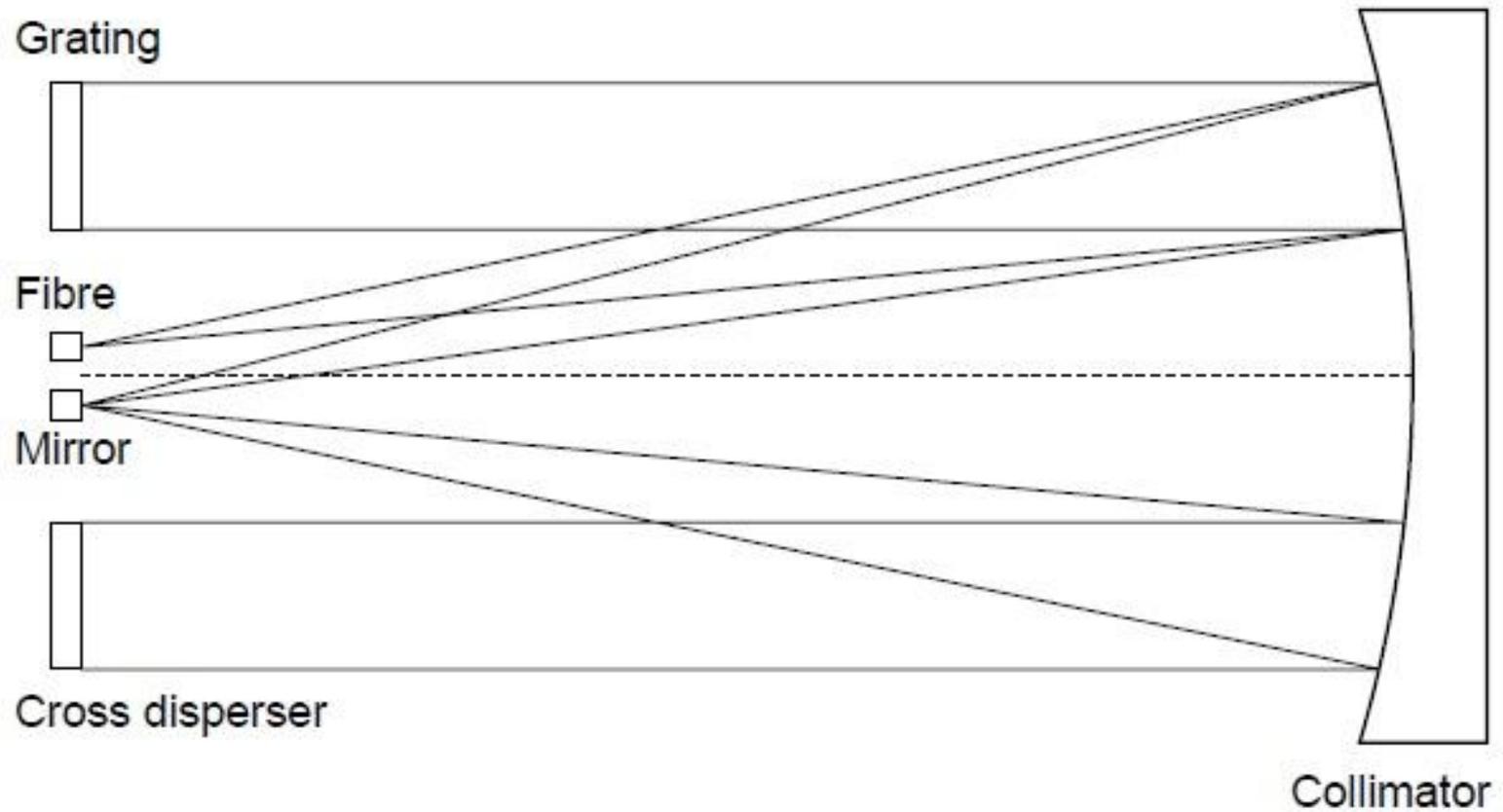


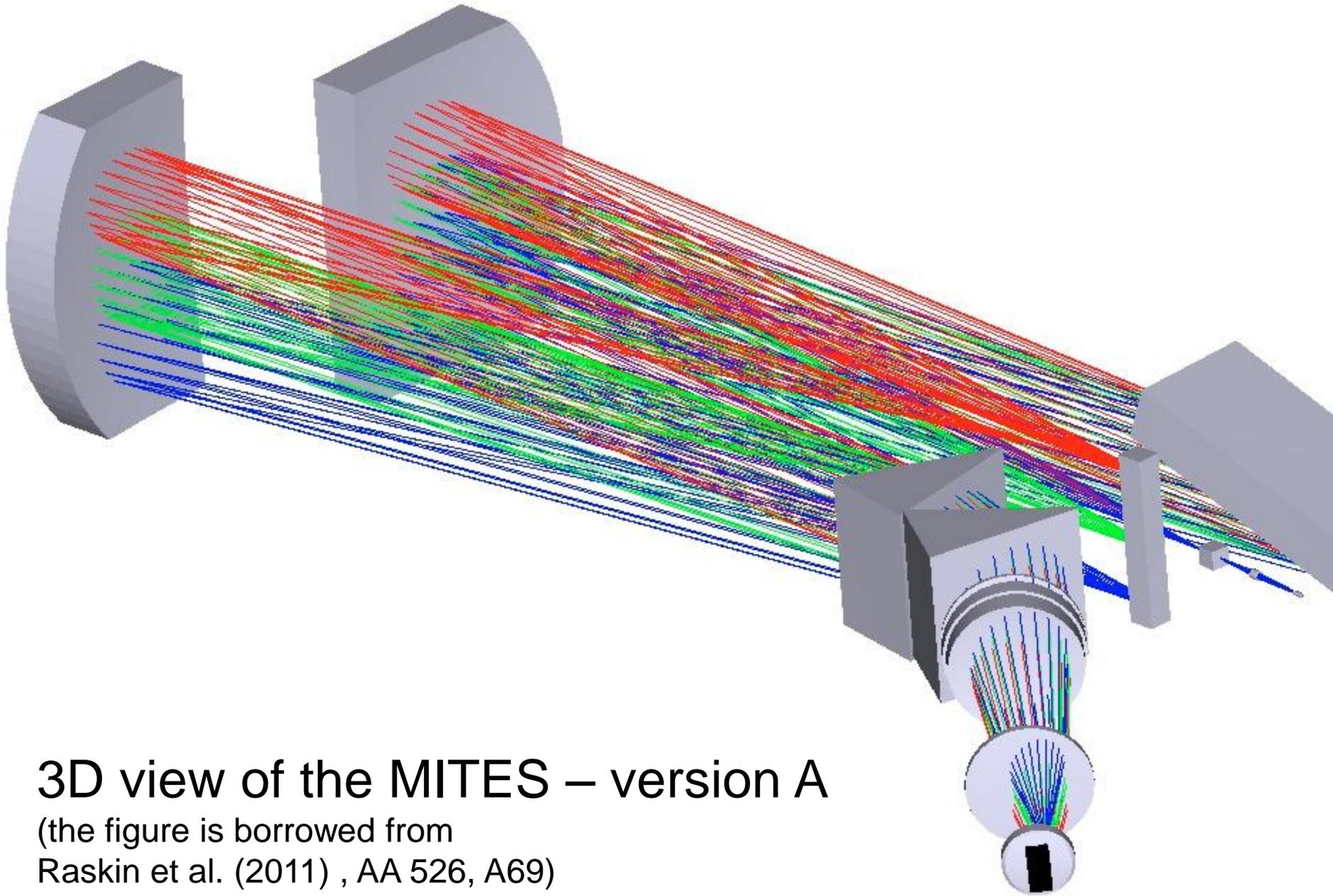
Edmund Optics
N/100, 4500\$





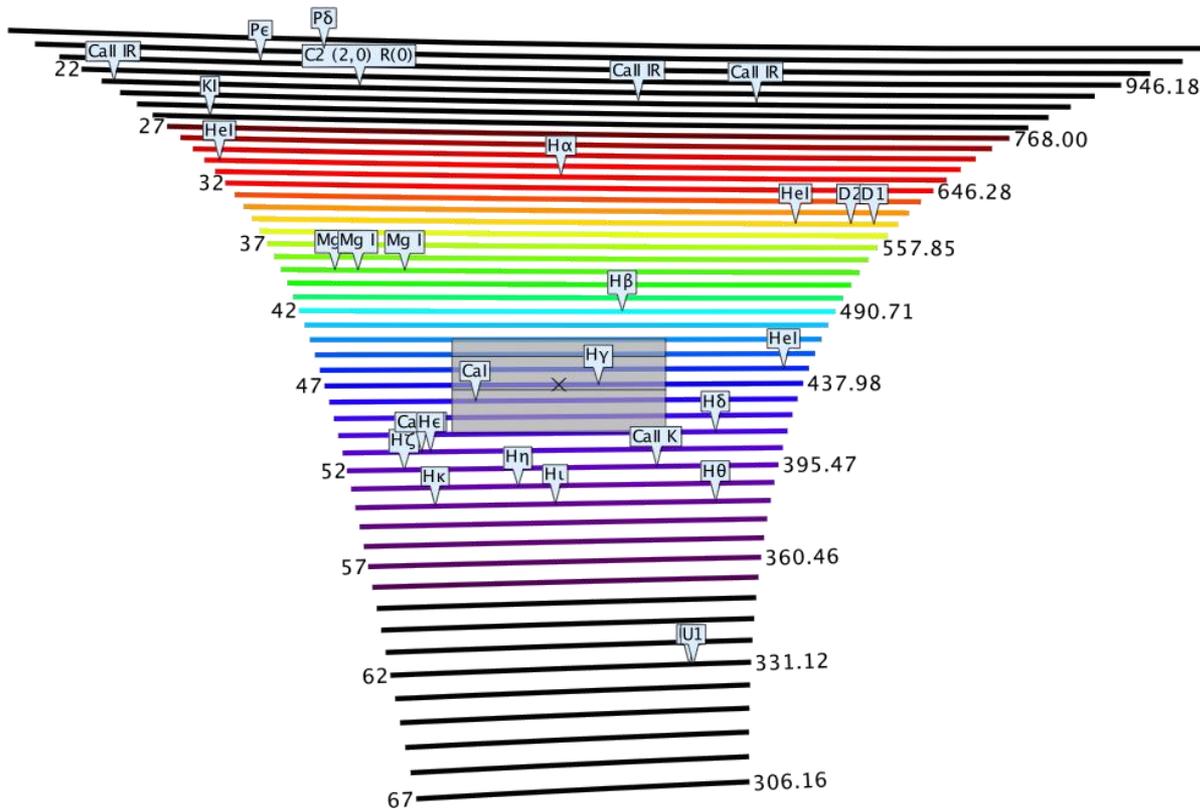
Principle of the white-pupil design



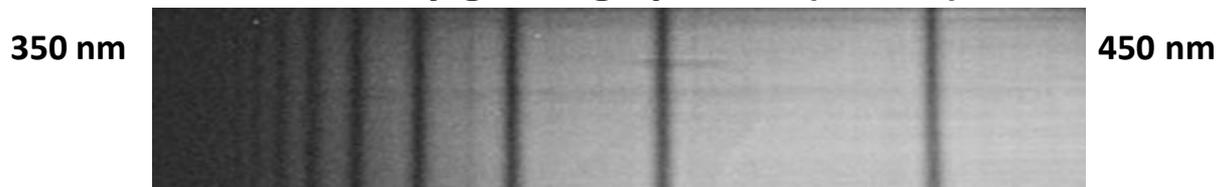


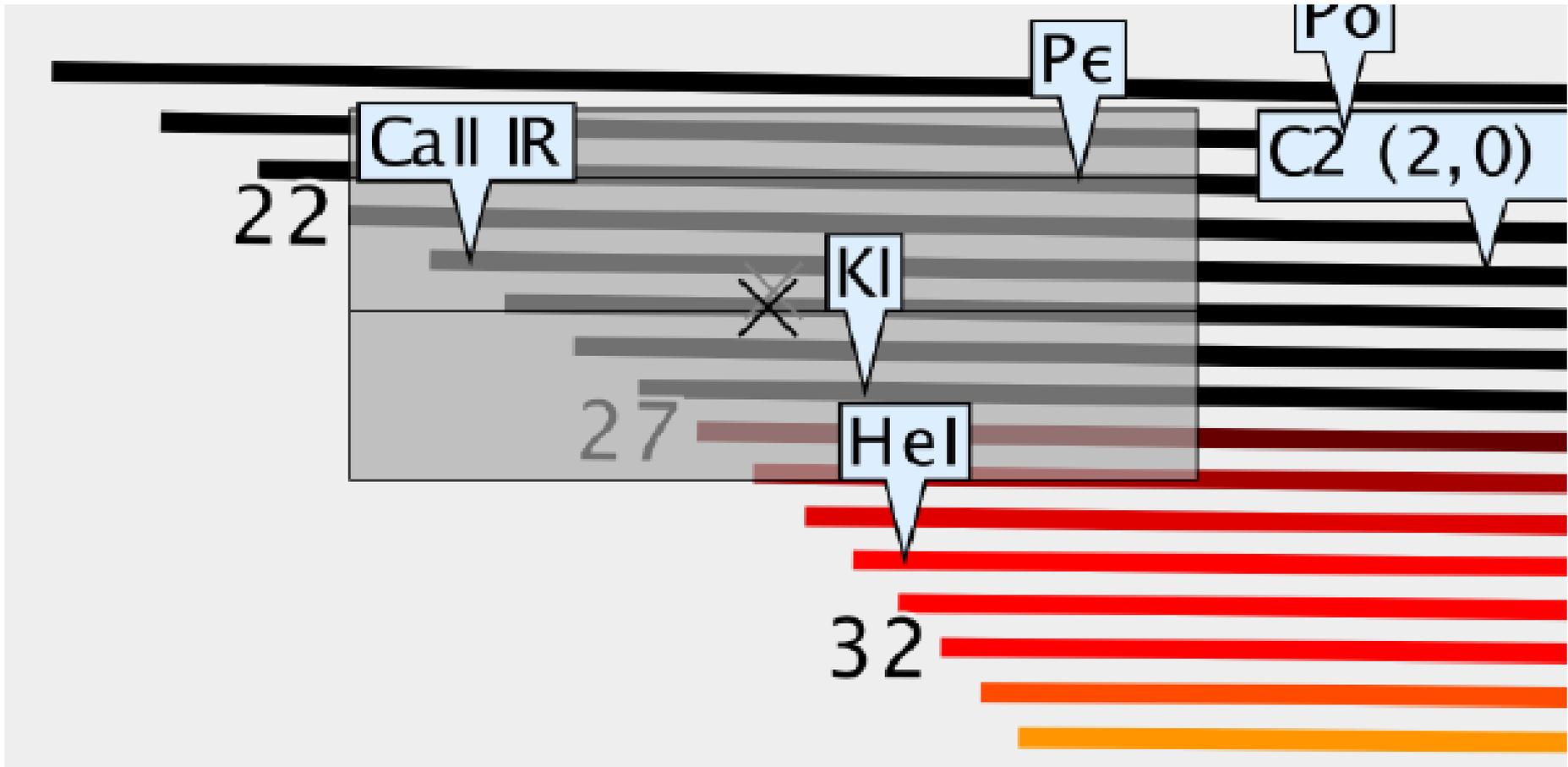
3D view of the MITES – version A

(the figure is borrowed from
Raskin et al. (2011) , AA 526, A69)



An echelle spectra (above) covers a much wider range of the spectrum than a high resolution ordinary grating spectra (down)





Metals

- Echelle grating.
- HERMES uses an echelle grating blazed with
- an intermediate blaze angle of $\theta = 69.74^\circ$ ($\tan \theta = 2.7$) as main
- dispersing element. The ruling of 52.676 grooves/mm nicely distributes
- the spectrum from 377 nm to 900 nm in 55 spectral orders
- over the rectangular CCD. The aluminium-coated ruled surface
- on a Zerodur blank measures 154×408 mm.