Advanced FBGs for sensing and dispersion control

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Hexatronic
Harsh Environment

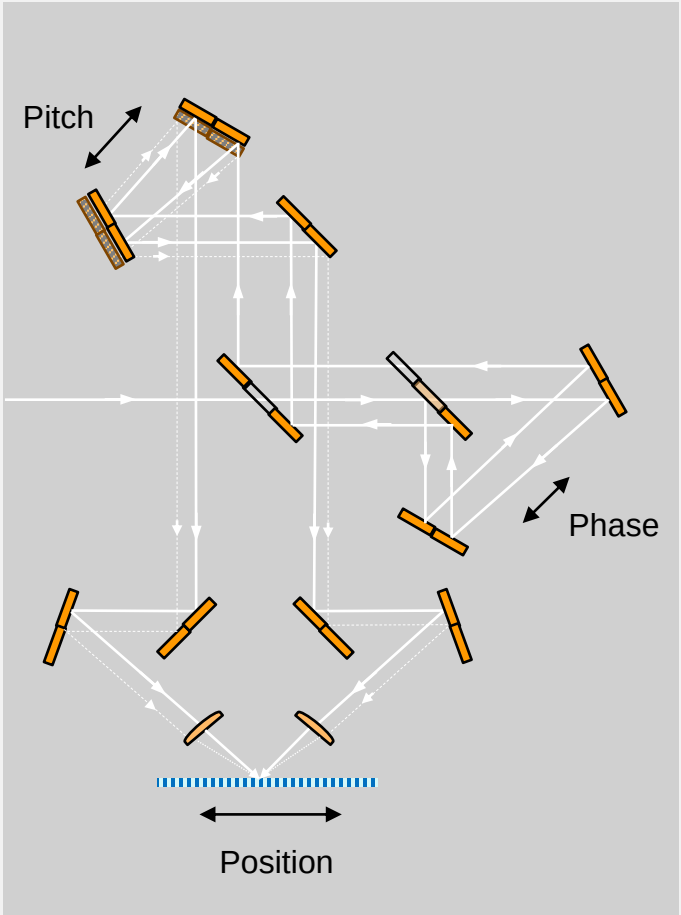
Who are Proximion?

- Part of Hexatronic Group, consisting of 54 companies and 1700 employees world-wide
- World leading manufacturer of long FBG for telecom and sensing, founded 1999.
- Factory and research center located in Kista outside of Stockholm, Sweden
- Large 1500 sqm clean-room with 14 grating writing machines
- 100 000+ FBG-products for dispersion control deployed in existing telecom networks
- 100+ industrial sensor system installations for temperature and strain-measurement operating world-wide

We specialize in customized gratings and full integration of FBG systems

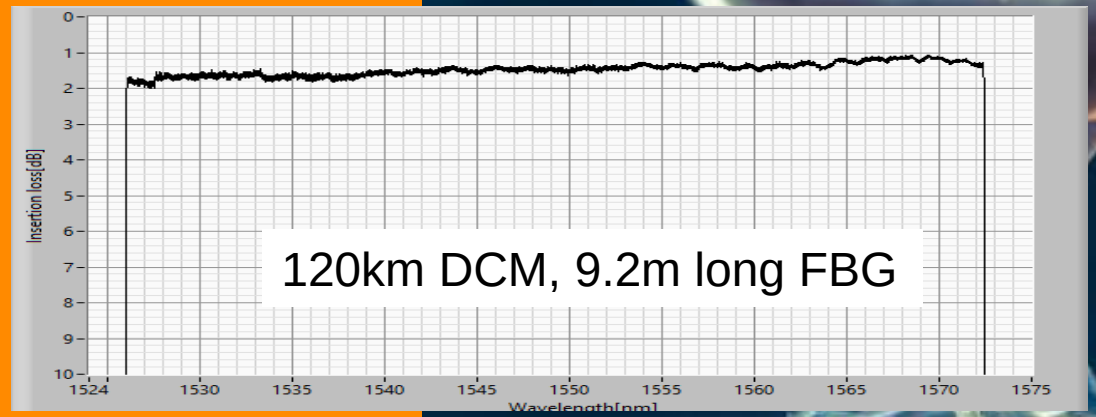
What’s special about Proximion’s FBGs?

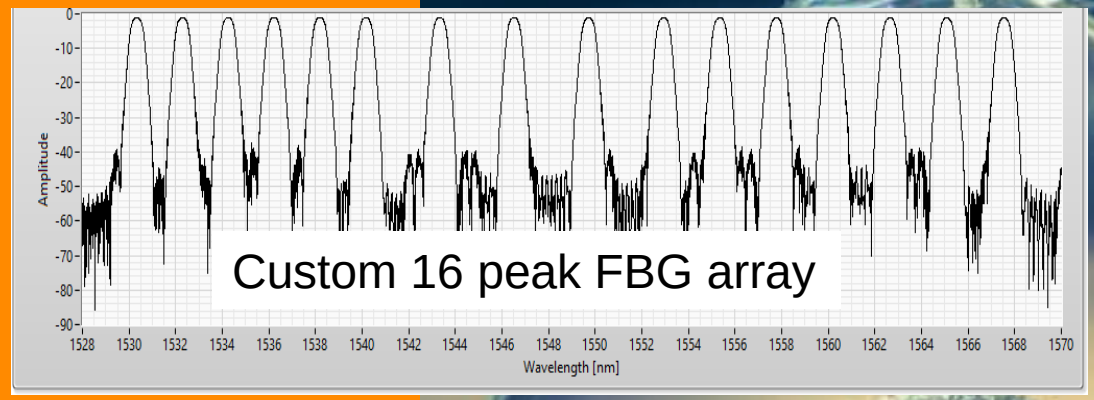
- Unique SW controlled manufacturing process – no masks required!
- Maximal length of 40m continuous FBG
- Continuously chirped grating
  - Tailored dispersion from 1ps/nm up to 50 000ps/nm
  - Wavelength range ~1000nm up to 2000nm
- Filter gratings
  - Arbitrary apodisation profiles i.e.for steep-edge filters
  - Absolute frequency accuracy
  - Reflectance range from ~0.1% to 100% (T>100dB)
- FBG arrays
  - Up to ~1000 FBGs on a single fiber
  - Flexible spacing and apodisation for high SMSR
  - Long-term stable sensors for ~10K to 650C operation



FBG usage today

- Dispersion compensation
  - Continuous chirped FBGs
  - Channelized chirped FBGs
  - Dispersion emulators for coherent training
- Sensing
  - Discrete FBG arrays for temperature and strain
  - Single FBG for accelation, pressure etc
  - Continuous FBGs for shape sensing
- Fiberlaser
  - High and low reflectance mirrors
  - Optical filters
  - Pulse stretching/compression





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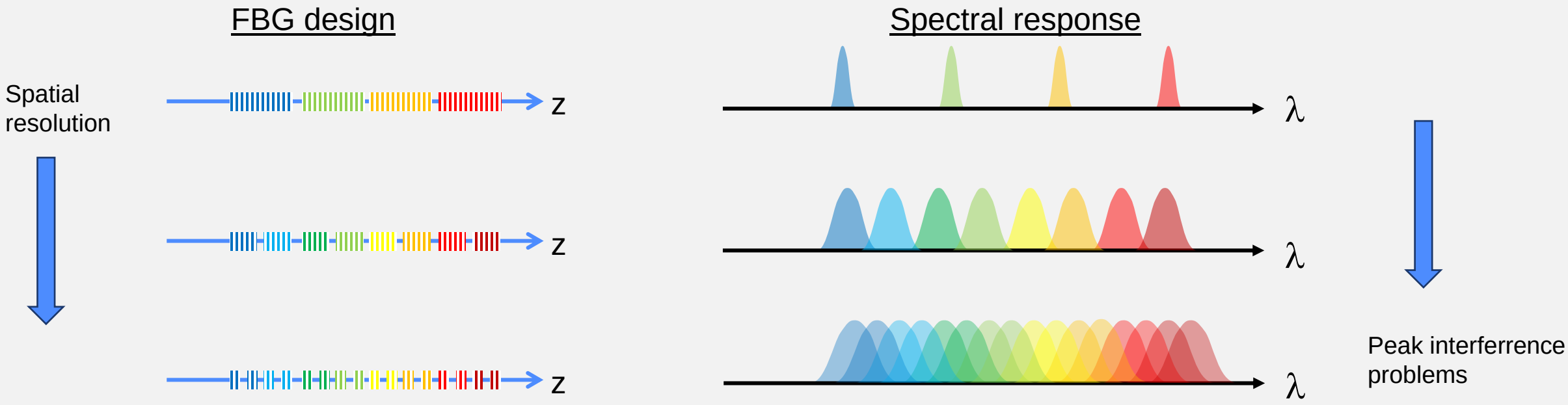
Rational for using chirped FBGs as temperature sensor?



Chirped FBGs gives maximal spatial resolution without peak interference

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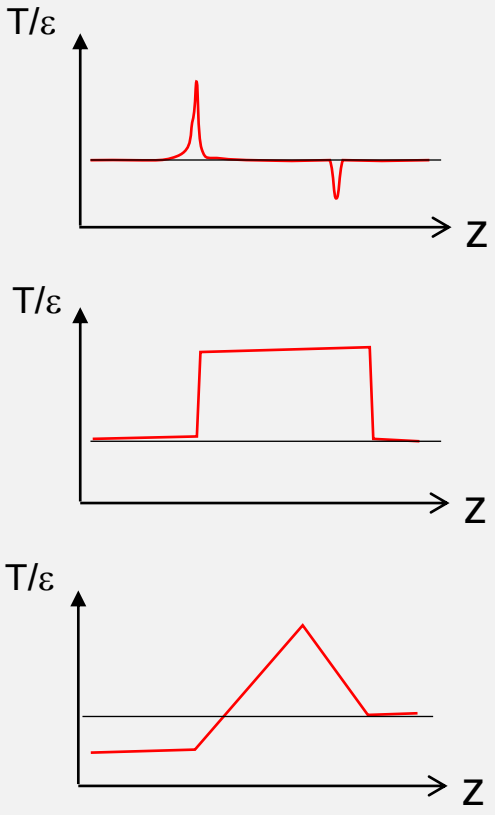
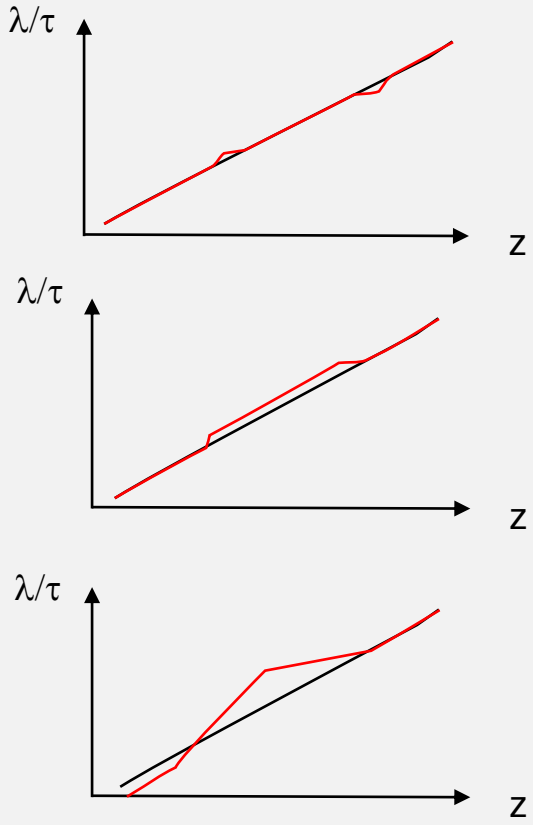
Spectral response of a chirped FBGS sensor

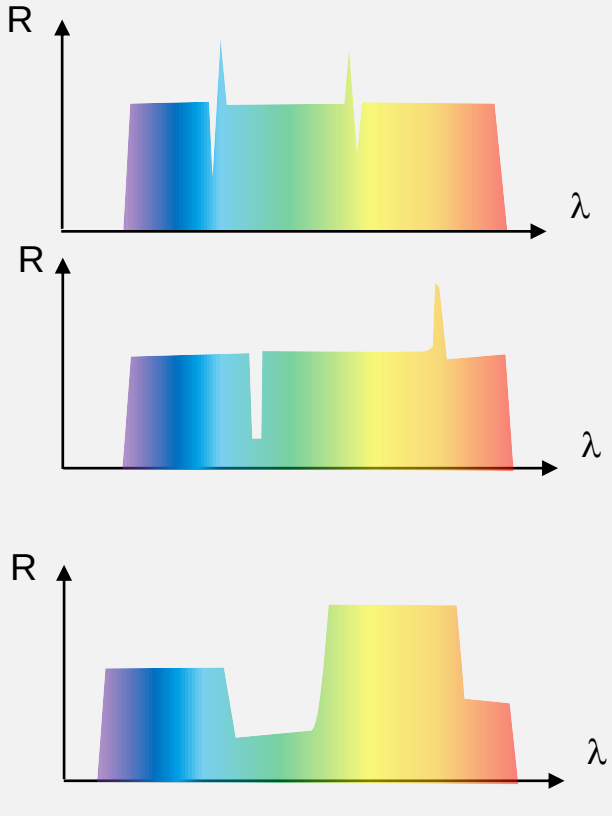
Temp or strain profile



Spectral/temporal profile



Spectrum



Algorithm

$$\varepsilon(t) = \frac{1}{1-p_e} \cdot \frac{\lambda^s(\tau) - \lambda(t)}{\lambda(t)}$$

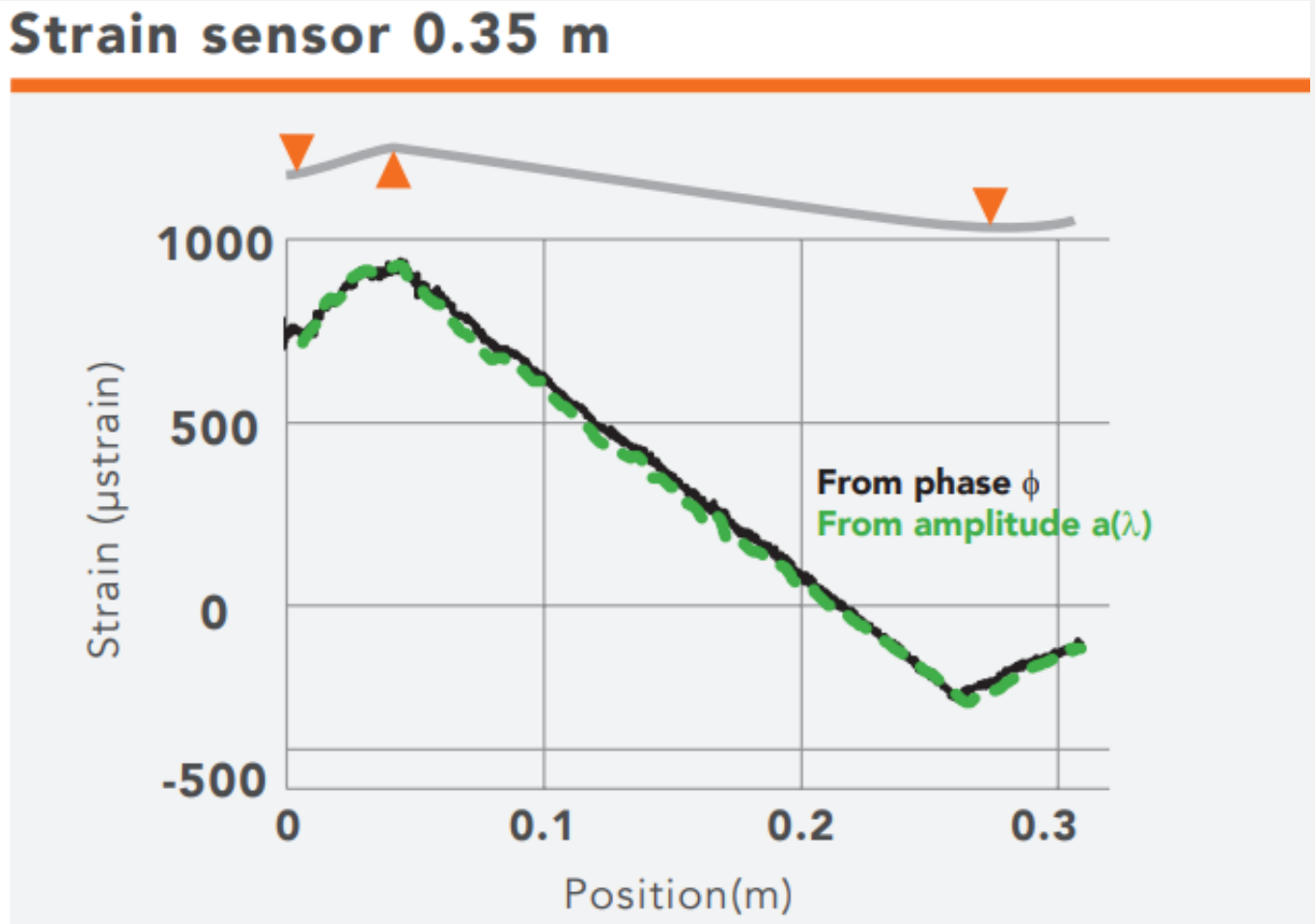
$$\frac{d\tau}{dt} = \frac{\lambda^s(\tau)}{\lambda(t)}$$

$$\frac{d\lambda^s}{d\lambda} = \frac{\ln[1-R(\lambda)]}{\ln[1-R^s(\lambda^s)]}$$

$$\frac{d\varepsilon}{dz} = \frac{\chi}{\lambda \cdot (1-p_e)} \cdot \left(\frac{d\lambda^s}{d\lambda} - 1 \right)$$

- Either phase or amplitude measurement possible

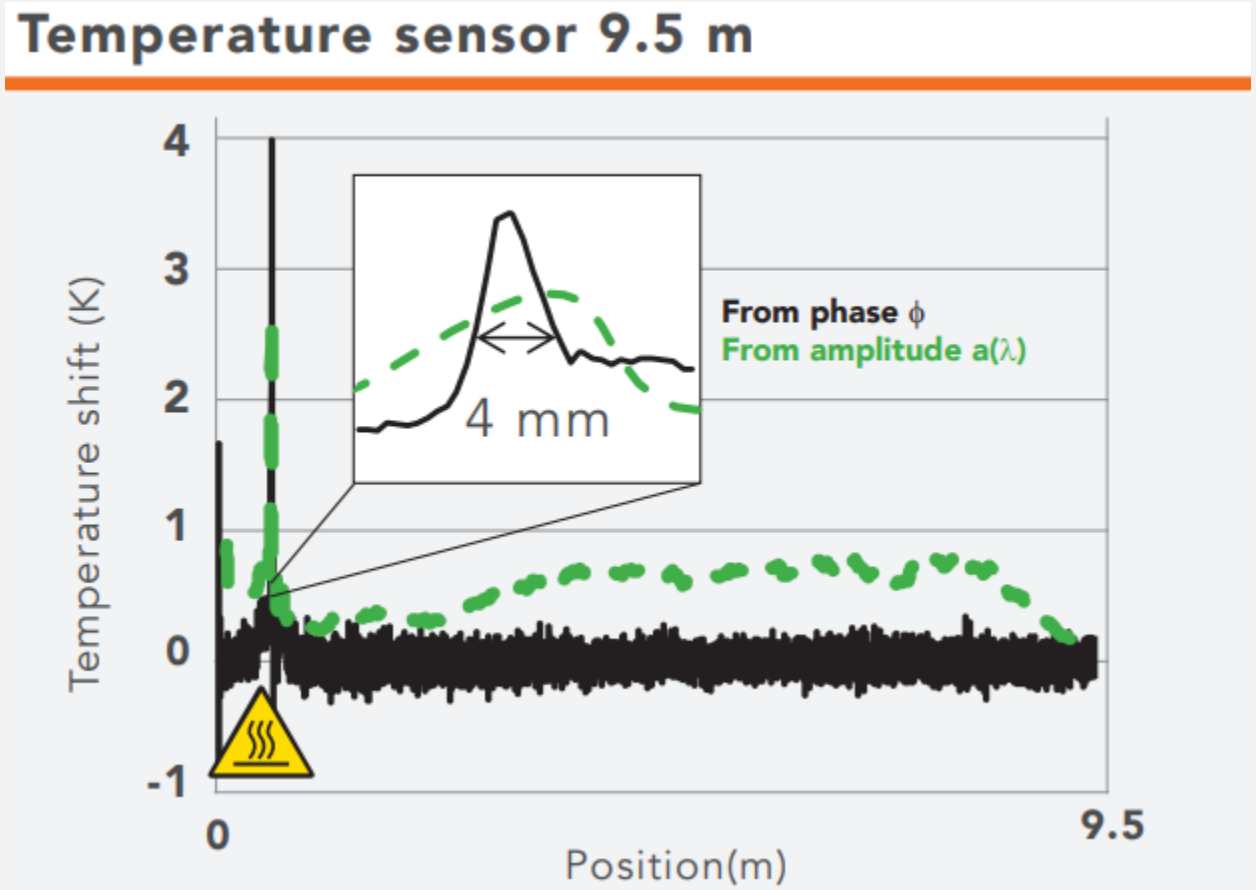
Example A: Strain sensing of a composite beam



Phase measuement
- OFDR (Luna)

Amplitude measurement
- Wistsense (Proximion)

Example B: Hot spot detection



- Tested grating is 9.5m long
- Detected hot-spot size ~4mm
- Position accuracy ~1mm

⇒ 2500 spatial sensor points
⇒ 1 mm spatial resolution

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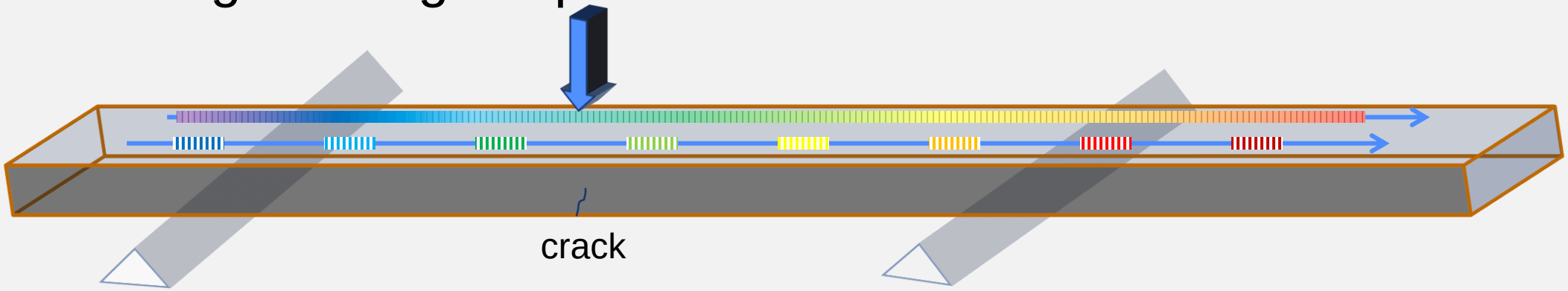
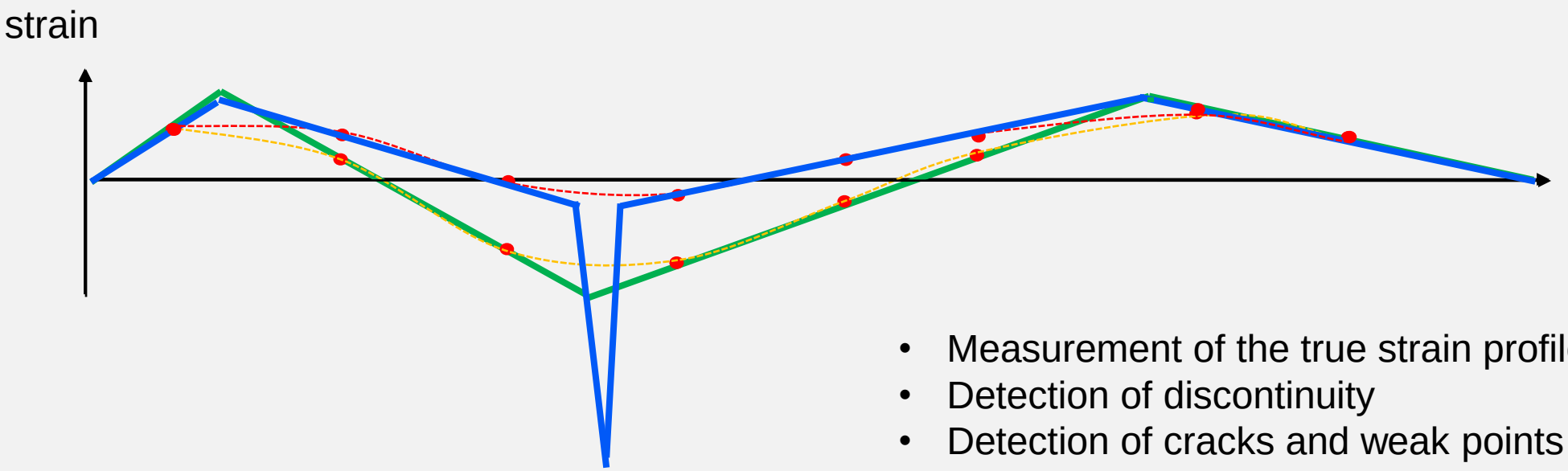
Advantages using chirped FBG as strain sensor





- Measurement of the true strain profiles
- Detection of discontinuity
- Detection of cracks and weak points

Comparison discrete vs continuous FBG

Discrete FBG array

+ Standard method
+ Peak detection algorithm
- Limited number of peaks
- High spatial resolution takes a lot of bandwidth
- Long sensors have dead spots

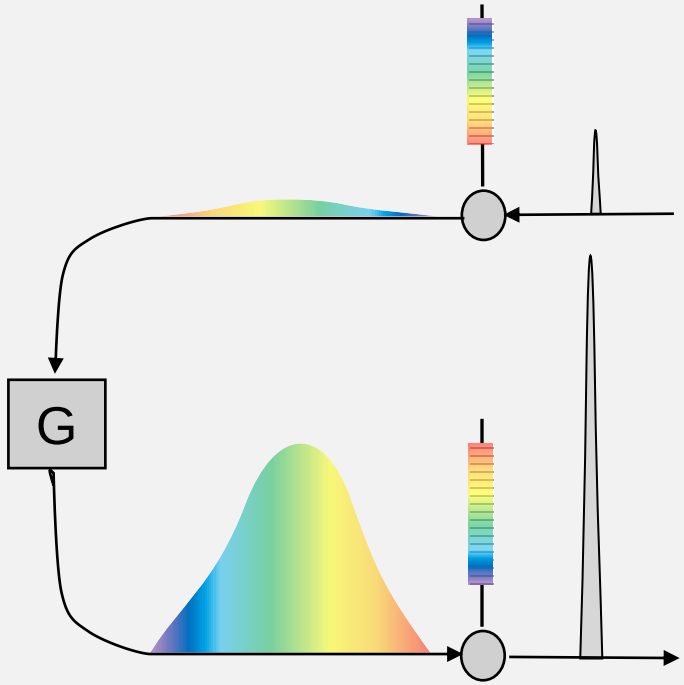
Continuous chirped FBGs

- Non-standard method
- Full spectrum analysis required
+ Infinite number of peaks
+ Maximal possible spatial resolution
+ No dead spots on the sensor

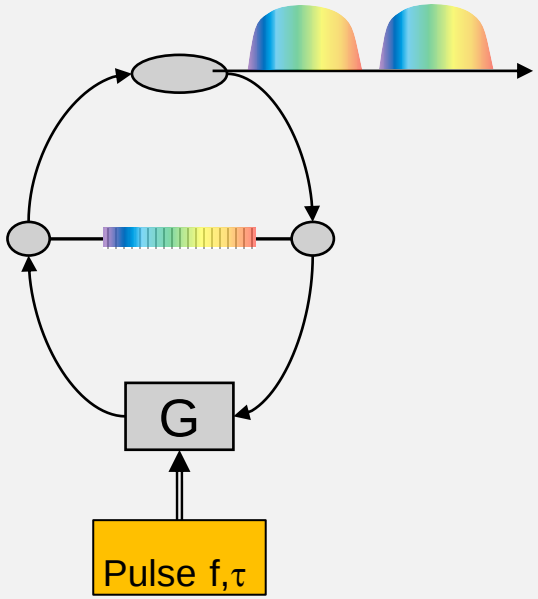
Continuously chirped sensors are great for some, but not all application!

Traditional (non-telecom) applications for chirped FBGs

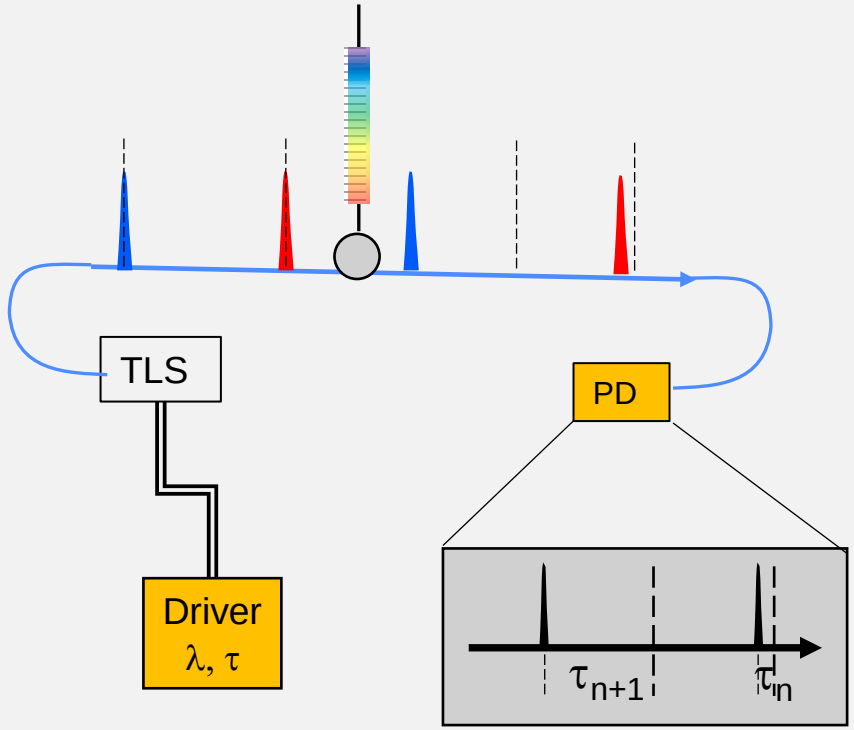
- Chirped pulse ampification



- Swept light sources (OCT)



- Variable delay lines



No standard products – FBG needs to be tailormade for each system system

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Q & A

- Are you currently using any FBGs today?
- What kind