# In-situ Optical Monitoring of Very Early-Stage Rail Wear and Rolling Contact Fatigue Crack Initiation in Laboratory Testing

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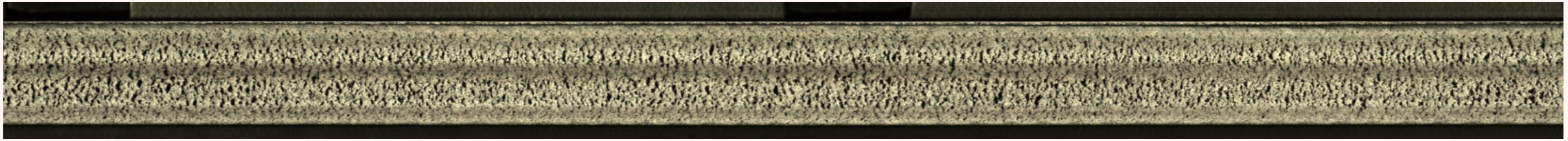
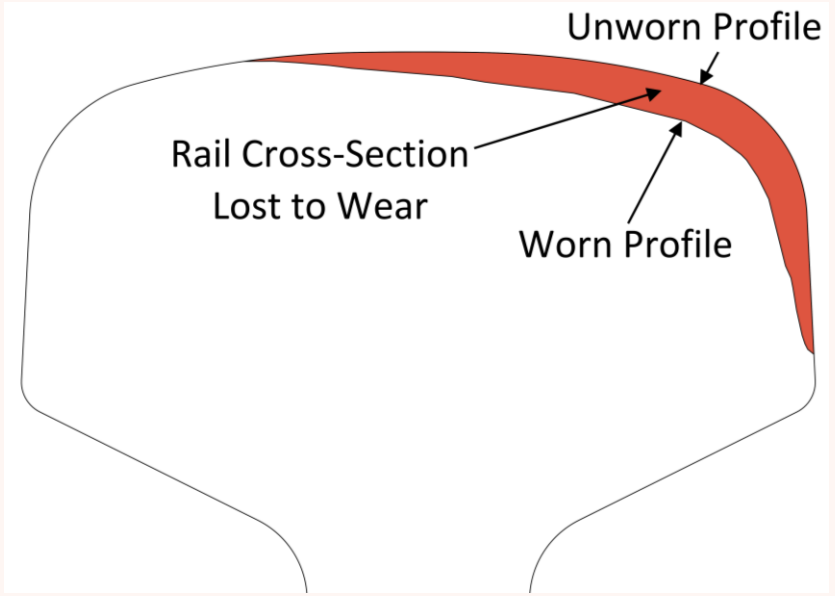
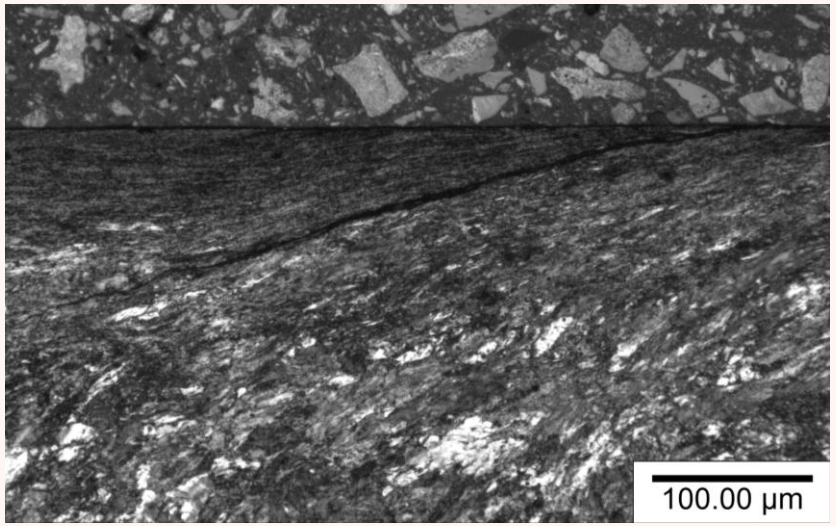


# Background

## Research Problem




- Wear and RCF cracks remain significant damage mechanism affecting Rail Steels
- Performance against Wear and RCF damage are crucial factors in the rail steel selection process
- Twin-disc tests commonly used to quantify rail steel wear and RCF performance
- Limited Information about wear and RCF performance obtained during tests



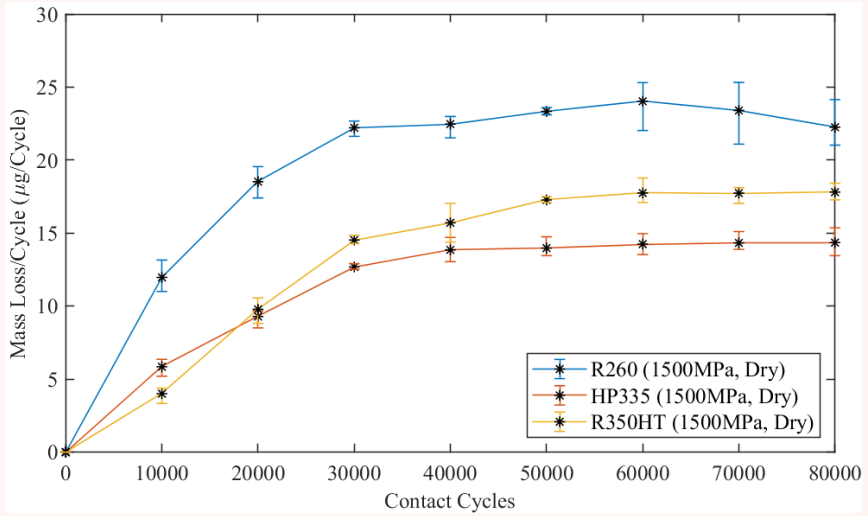

A. Wilby (2019)

# Background

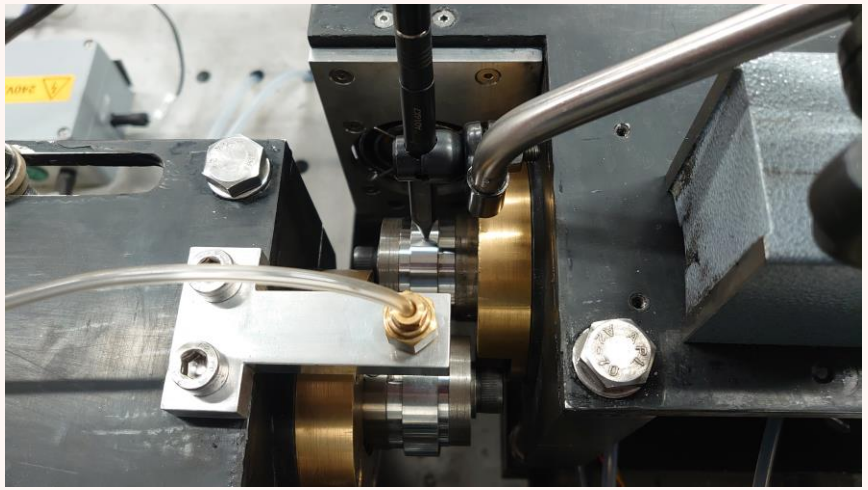
## Previous Approaches to Enhance Data Collection

- Previous Approaches to enhance data collection
  - Mass loss measurements
  - Eddy current sensors
  - Electro-magnetic arrays
  - Optical systems

- **Research Aim:** Design and develop a new optical monitoring system capable of photographing in detail a twin-disc samples running surface while rotating at speeds up to 400 rpm during twin-disc tests



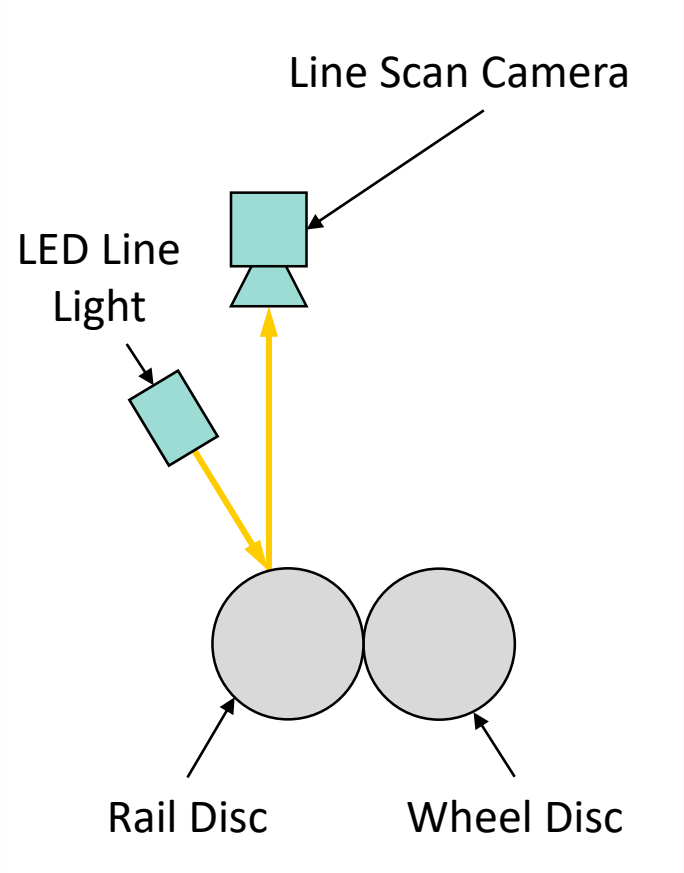

A. Wilby (2021)

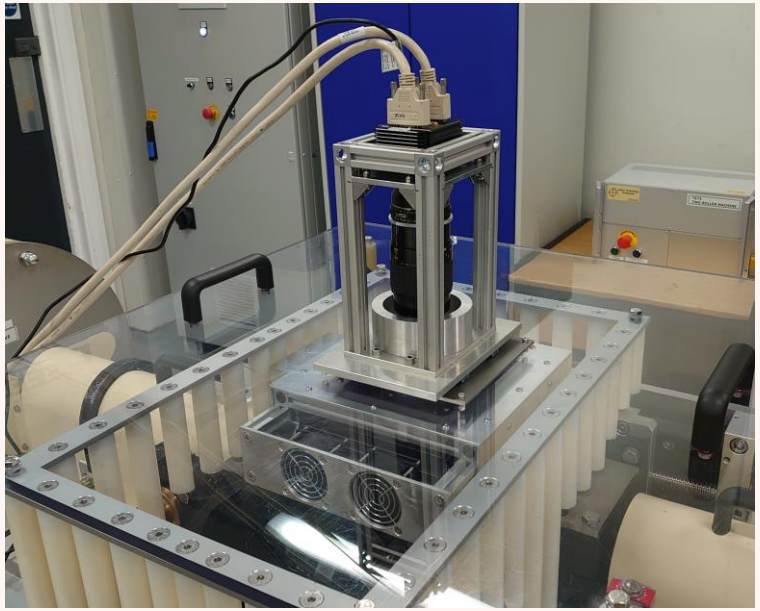


# Design of the New In-Situ Optical Monitoring System

## Design Overview

- Optical monitoring system designed as two removable modules
- Connected via an intermediate slider and bolted onto twin-disc machine rail rolling driveshaft
  - Allows the entire system to move with the machine helping create stable images

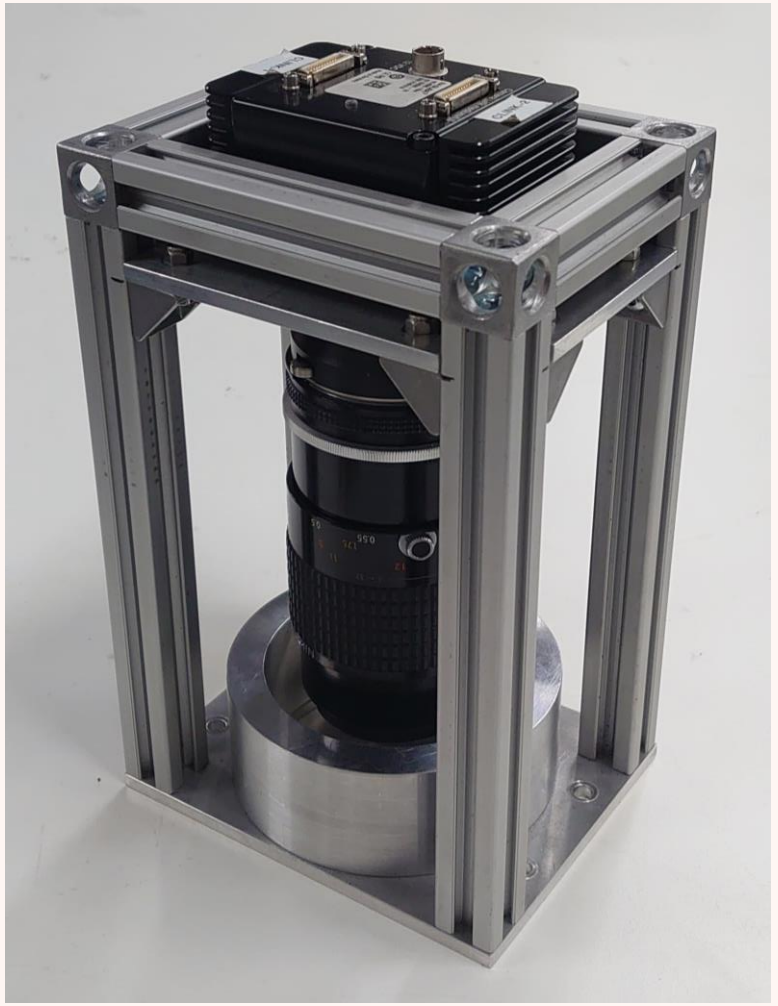


# Design of the New In-Situ Optical Monitoring System

## Line Scan Camera Module

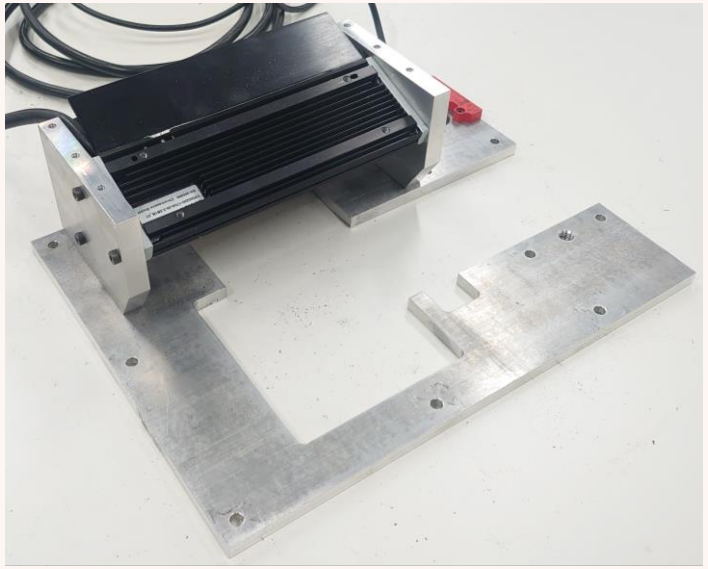
- Images captured using a Basler spl4096-kc line scan camera with a Nikon AL-S 105mm f/2.8 macro lens
  - Spatial Resolution = 20µm/px
- Required capture Line rate = 20µs
  - Exposure time = 19µs
- Designed depth of field = 1mm
  - Aperture = f/5.6
- Camera vertical height can be adjusted to aid in focusing the images
- Images transferred to a dedicated computer and processed using XCAP image processing software

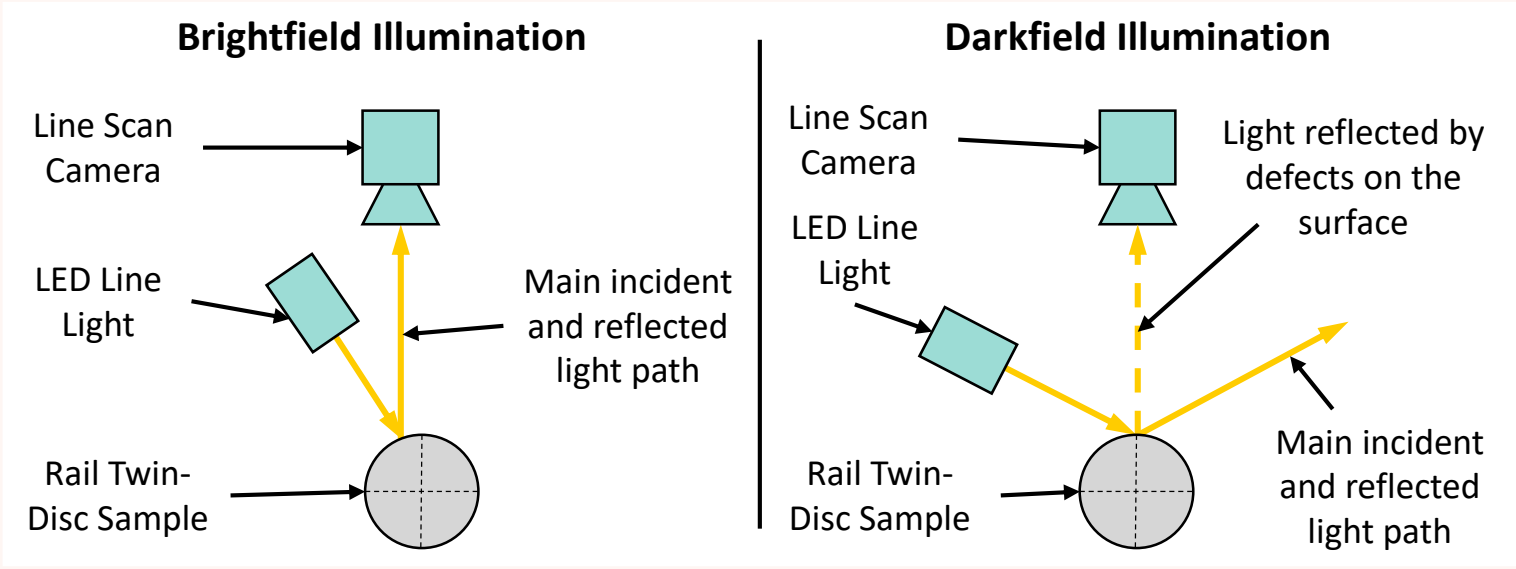


# Design of the New In-Situ Optical Monitoring System

## Line Light Driver Module

- Twin-disc illumination provided by a Chromasens Corona II LED line light
  - Light output up 500,000 lux of illumination at the 95mm working distance
- LED line light controlled by a Chromasens XLC4 control unit, which is programmed using Chromasens XLC4 commander software
- Can be adapted to allow tests to be conducted with either brightfield and darkfield illumination





# Trial Test Programme

- **Study 1** - Assess how the optical monitoring system was able to visualise wear flakes and RCF cracks
  - Twin-disc samples tested:
    - R260 wear twin-disc sample previously test against R8T wheel steel (1200MPa, 1% slip, dry) up to 80,000 contact cycles
    - Calibration disc with a spark eroded RCF crack
    - Unworn twin-disc sample
- **Study 2** – Assess the performance of the system during a test when the disc are in contact
  - R260 rail steel against R8T wheel steel for 1200MPa, 1% slip, dry contact conditions up to 40,000 contact cycles
  - Image captured every 30 secs

Wear Twin-Disc Sample

RCF Calibration Disc

# Trial Test Results

## Rails Steel Surface Damage Observation Assessment

- Wear Twin-Disc Sample
  - **Brightfield illumination** – Outline of wear flakes easily identified by the shadow cast onto the sample
  - **Darkfield illumination** – Difficult to distinguish bright spots created by wear flakes and the sample surface roughness


Unworn Disc (Brightfield) | Unworn Disc (Darkfield) | Wear Flake Disc (Brightfield) | Wear Flake Disc (Darkfield) | RCF Calibration Disc (Brightfield) | RCF Calibration Disc (Darkfield)

# Trial Test Results

## Rails Steel Surface Damage Observation Assessment

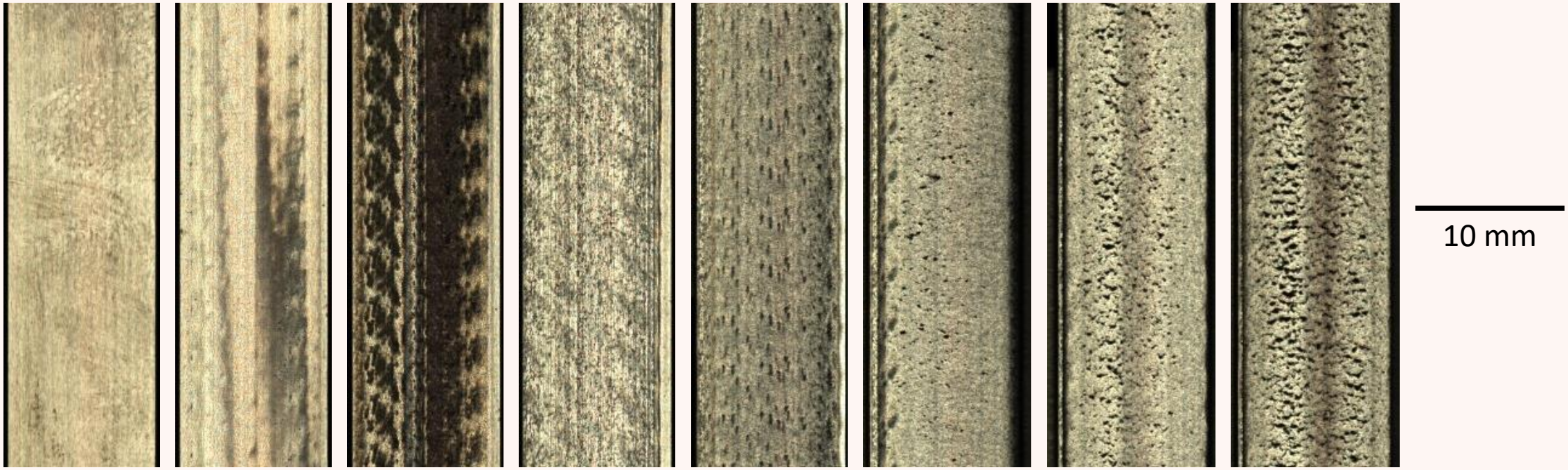
- RCF calibration twin-disc sample
  - **Brightfield illumination** – Outline of crack easily identified by the shadow cast onto the sample
  - **Darkfield illumination** – Very contrast between the crack and twin-disc samples running surface to able to easily identify it


Unworn Disc (Brightfield) | Unworn Disc (Darkfield) | Wear Flake Disc (Brightfield) | Wear Flake Disc (Darkfield) | RCF Calibration Disc (Brightfield) | RCF Calibration Disc (Darkfield)

# Trial Test Results

## Dry contact test

- Images obtained barely affected by the movement of the machine
- Capable of visualising the surface development of twin-disc samples
  - ➢ Initial darkening stage followed by gradual development of easily recognisable wear flakes



# Conclusions

- The new optical monitoring showed that it is capable of optically monitoring the running surface of 47mm twin-disc sample rotating at 400 rpm
- Brightfield illumination showed to be best at visualising the wear flakes, RCF cracks, and tarnishing of the disc surfaces
- Darkfield illumination was better for imaging surface roughness development on a twin-disc sample
- The system is able to capture detailed stable images of the twin-disc samples running surface when subject to movement created by the machine when the discs are in contact