# MANUFACTURING OF X-BAND ACCELERATING STRUCTURES: METROLOGY ANALYSIS AND PROCESS CAPABILITY

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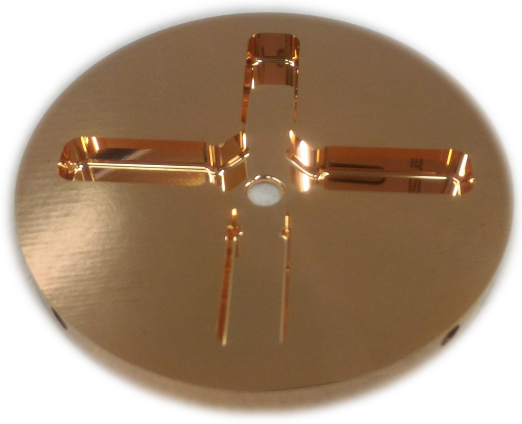
## Introduction

CLIC baseline design represents a diffusion bonded stack of cylindrical Oxygen Free Electronic copper discs, which are machined to form a cavity of the RF cells. The discs (or cell) geometry and high order modes damping loads had been extensively optimized in order to maximize the RF-to-beam efficiency, and to meet the beam dynamics and high gradient RF constraints.

Sub-micrometre tolerances are needed to reach the accelerating gradient goal of **100 MV/m** if no tuning is applied and if no temperature correction is allowed to the accelerating structure.

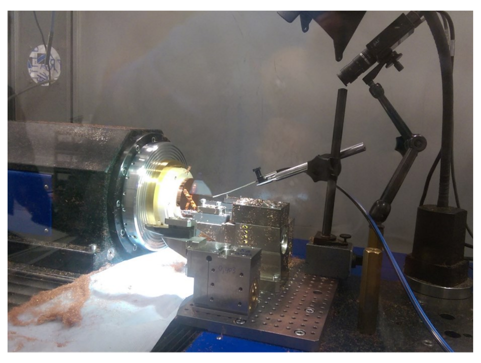
## Manufacturing



Main design changes

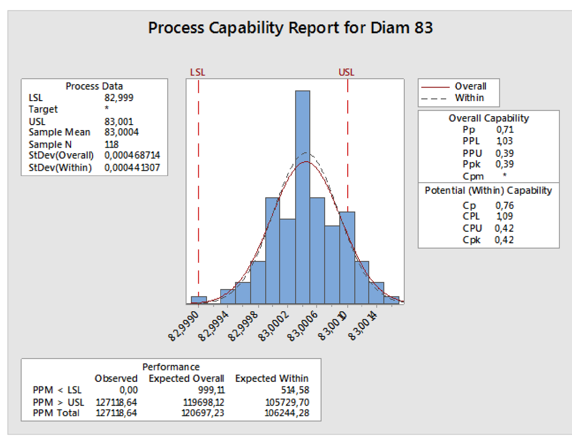
- "Nose" of the waveguide from an elliptical geometry to a **4-th order polynomial function**.
- The **radius** at the bottom of the RF waveguide was **increased from 0.5 mm to 1 mm** to allow the use of bigger milling cutter
- Disc **diameter was increased from 74 mm to 83 mm.**

The total fabrication included four structures: **118 discs**: the **biggest amount of discs** ever produced in a single order. The parts were produced by a combination of **Ultra-Precision diamond fly cutting, milling and turning**.



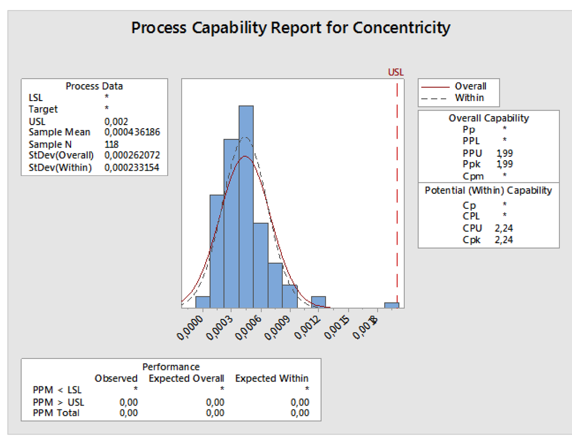
## Process Capability

Process capability compares the output of an in-control process to the specification limits by using capability indices. **Cpk** is an **index** (a unitless number) which measures how close a process is running to its specification limits.



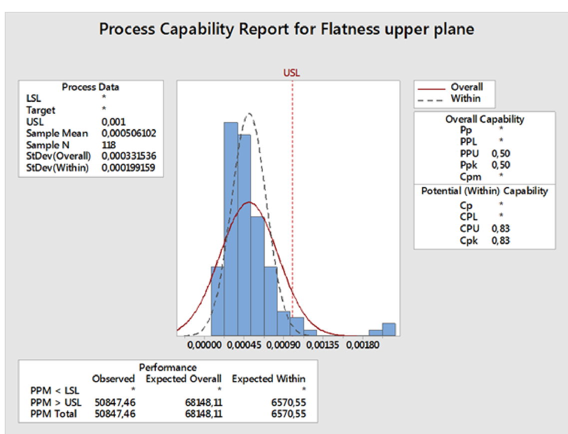

Ø83 mm has a **Cpk = 0.42** which can be translated into **106244** PPM.

At the beginning of the fabrication the tolerance was relaxed from ±1 µm to ±2 µm. The process reaches a **Cpk = 1.1** thus **14 PPM**.



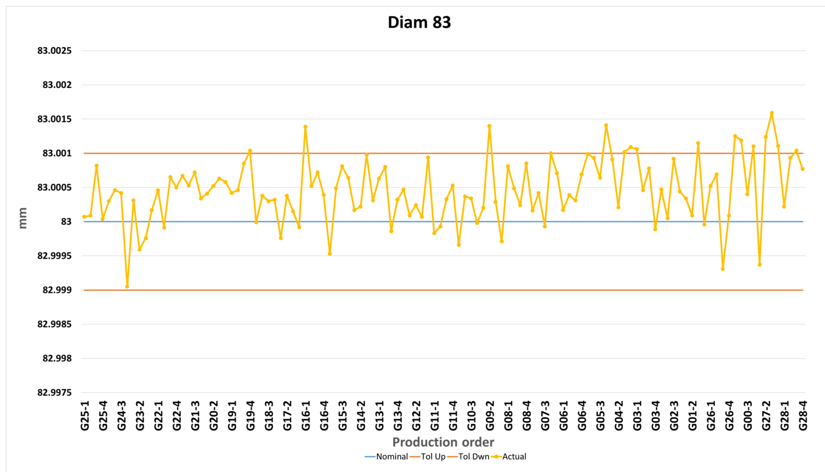

Concentricity of the iris and external diameter has a Cpk shows an impressive **2.24** hence **0 PPM**

Flatness of reference A has a **Cpk = 0.83**. It is greatly affected by the parts out of tolerance.

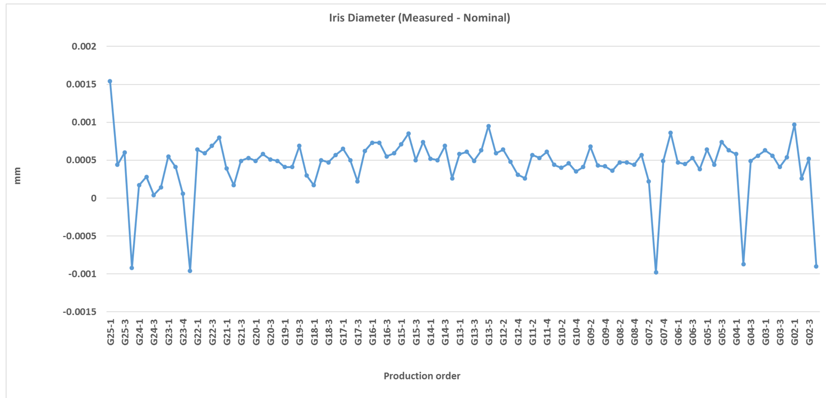



## Production Order

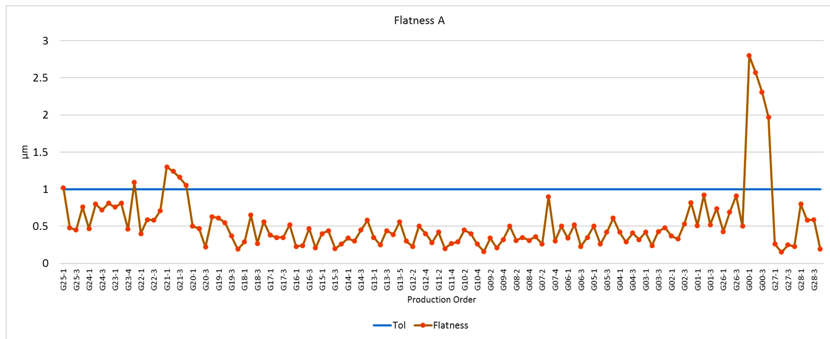
**Normal variability** can be observed along with 14 parts out of tolerance.



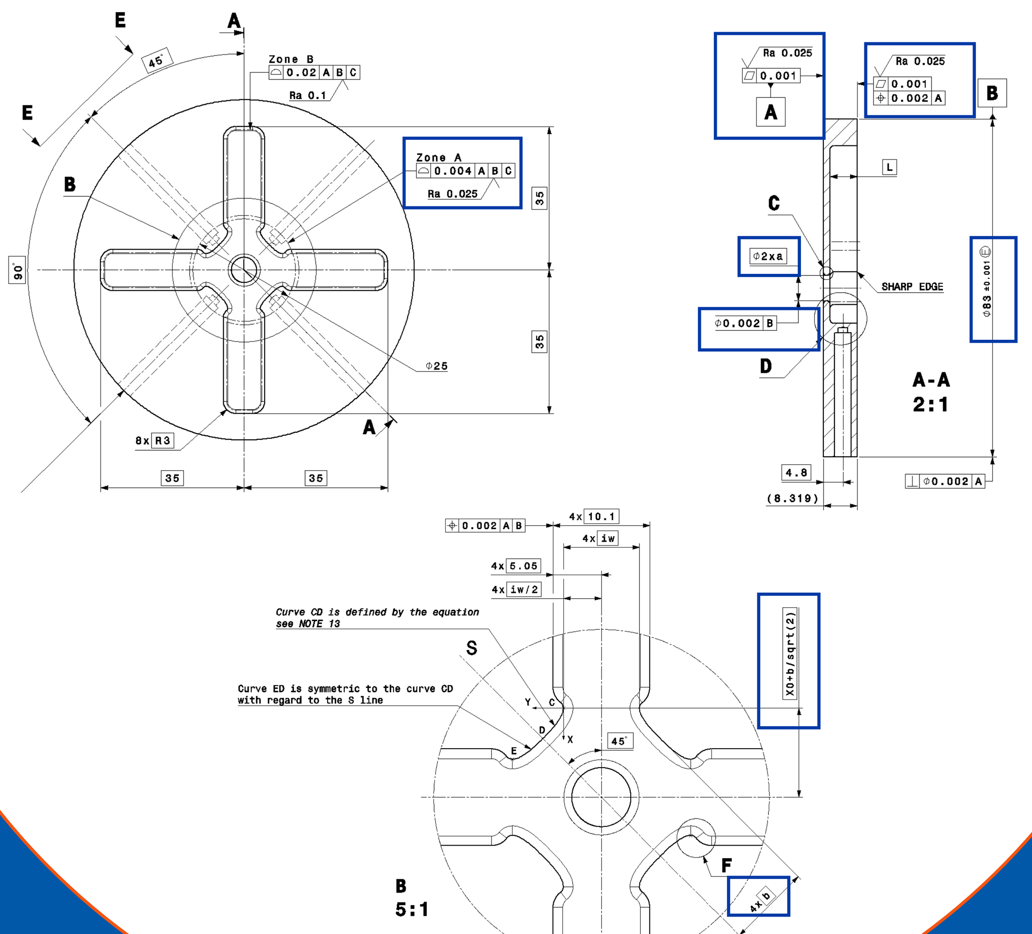

The process systematically **created slightly bigger iris diameter** (in average 0.5 µm).



A process modification was made and, as a result, process variability improved.




## TD26 Regular cell

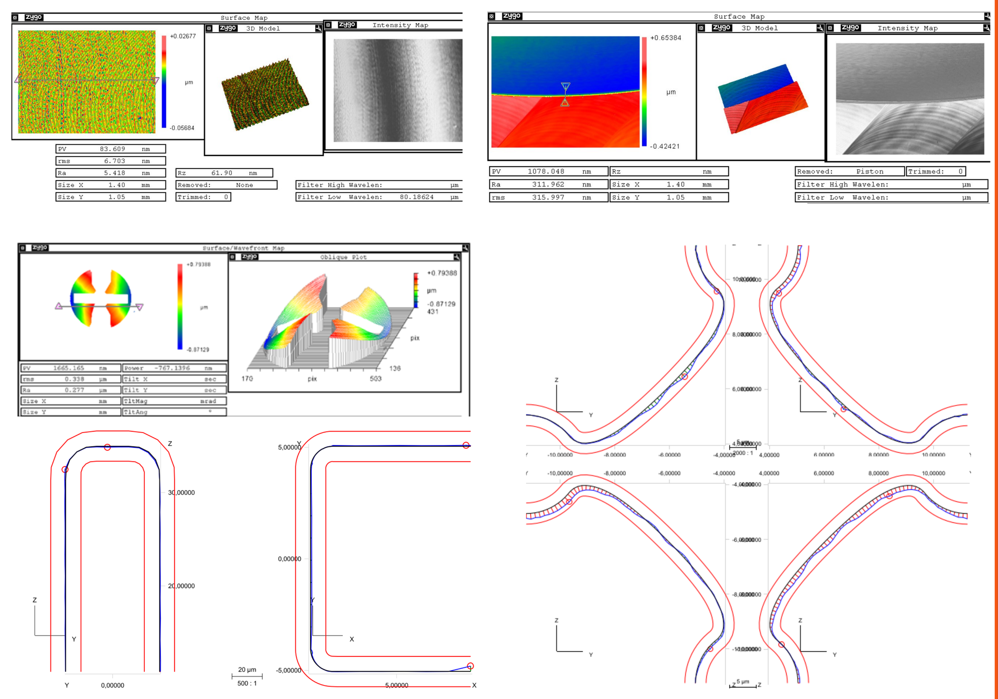



## Roughness and Form

Roughness was evaluated at six different positions.

The roughness measurements were largely conform to the specification.

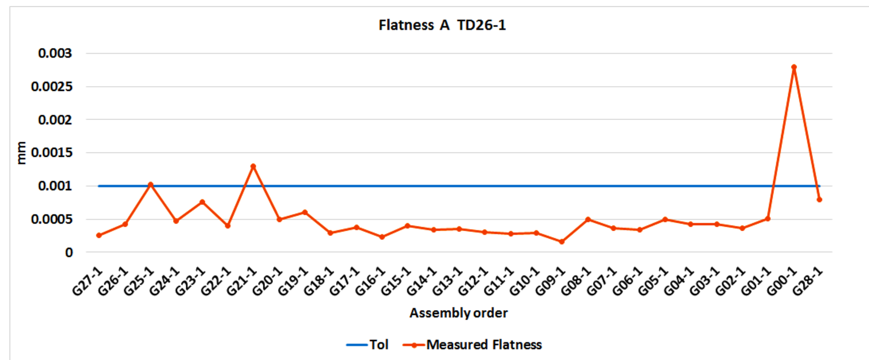
Shape tolerances of the iris and waveguides were also controlled. All discs were largely in tolerance.

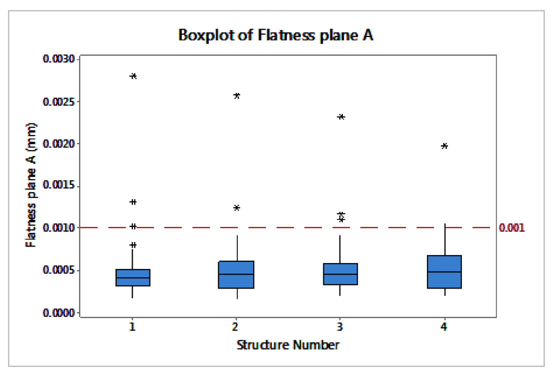


## Assembly Order

The objective is to identify the variability, in a single graph, of the 29 discs that builds up one structure.

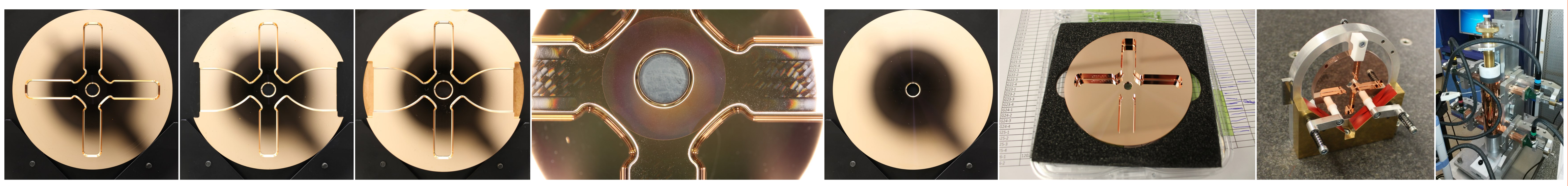
The boxplot shows that first and third structure have less variability compare to second and fourth structures. Outliers are present in the four structures: coupler cells (G00) and to regular cells out of tolerance at the beginning of the production.




## Conclusions

The production analysis allowed us to identify changes in the manufacturing of the parts: a second fly cutting operation was added in order to improve the flatness. Moreover, the assembly analysis allow us to identify variability among the different structures. Besides some specific problems (i.e. flatness at the beginning of the production), the processes are under statistical control with few parts out of the specifications. The concentricity of the iris w.r.t. external diameter has even a large Cpk. Shape accuracy and roughness of the different features are largely conform. Considering the tight tolerances and the large production, results are positive. An important benefit for CLIC is the correct evaluation of supplier performance by identifying the technically and economically correct tolerances.



## TD26 Prototype

The prototype is a tapered, damped, 26 regular cells with integrated compact couplers.