BANKNOTE TECHNOLOGY REPORT 2024

AUTHENTIX

Redefining security in the Nano Optic era

FACT BOX

- Counterfeit Resilience:

  Our proprietary algorithms and specialized manufacturing techniques establish a new standard of security, making reverse engineering virtually impossible.

- Ease of Authentication:

  Our features are intuitive and simple, developed with decades of anti-counterfeit expertise.

- Durability:

  Tested by third parties, our technology ensures longevity and integrity, even in challenging environments.

- Integration:

  QUANTUM™ is compatible and proven with paper, polymer and mixed substrates. While seamlessly integrating into existing manufacturing workflows.

- Innovation:

  Positioned at the forefront of security technology, Nano Optics represents the dawn of a new era in authentication.

In a groundbreaking move set to reshape the industry landscape, Authentix® has recently acquired the previously known Nanotech division from META® Materials Inc. Promising to unlock new potential and synergies, this strategic acquisition marks a pivotal step towards enhanced innovation and market leadership.

Authentix is proud to expand their currency portfolio with the introduction of QUANTUM™ stripe, the world's first fully animated, Nano Optic banknote security product.

REDEFINING SECURITY IN THE NANO OPTIC ERA

In today's ever-evolving landscape of security feature technology, the pursuit of effective solutions to combat counterfeiting and ensure product authenticity remains paramount.

At Authentix, we recognize the importance of staying ahead of criminals by continuously innovating and pushing the boundaries of what is possible. Leveraging nanostructures and proprietary algorithms, Nano Optics represents a new era in authentication, offering unparalleled benefits across the 5 core pillars of security features:

1. Counterfeit resilience relies on innovative technology and the use of non-commercially available materials, making reproduction costly.
2. Authentication should be effortless, with features easily recognizable and intuitive for users to verify.
3. Durability is paramount, withstanding environmental effects to maintain trust in the security feature for the lifecycle of the banknote.
4. Integration enhances security through seamless design while being developed to ensure compatability with industry standard application equipment.
5. Innovation is a continuous process, providing a platform for long term development without succumbing to "innovation burnout."

TECHNOLOGY TIMELINE

YESTERDAY'S TECHNOLOGY

In the domain of security feature technology, progress has traditionally revolved around three primary technologies: holograms, colour-shifting films or inks, and micro-optics.

Despite a period of evolution and innovation, these technologies' foundational principles have remained unchanged for decades. Moreover, the widespread availability of materials, equipment, and origination methods in commercial markets has expedited the counterfeiters' ability to replicate them, putting their security measures at risk of being surpassed.

As security feature providers, it is imperative for us to stay ahead of counterfeiters by continuously seeking solutions that integrate the latest non-commercially available technology, offer seamless integration, and ensure straightforward public authentication. It is with this commitment in mind that we introduce Nano Optics—a groundbreaking technology poised to redefine security features.

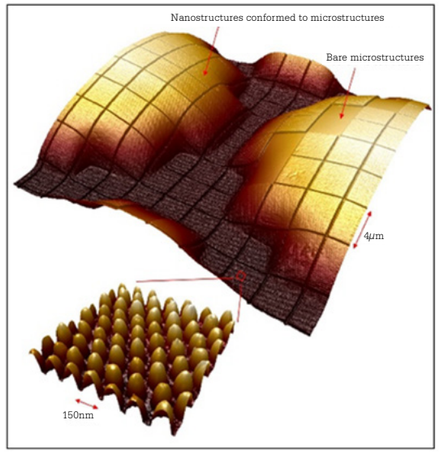
UNDERSTANDING NANO OPTICS

Authentix Nano Optics are based on the principles of nanostructures to create structural colour, mirroring the phenomena observed in nature such as the vibrant hues of Blue Morpho butterflies.

SEM IMAGES - BLUE MORPHO BUTTERFLY WING

The Blue Morpho butterfly showcases one of nature's most remarkable examples of structural coloration. Surprisingly, these butterflies possess no inherent pigmentation; when viewed under direct light, they appear transparent. Their vivid blue hue results from a complex interplay of macro, micro, and nano-scale structures on their wings. These structures selectively filter incoming light, allowing only blue wavelengths to be captured and reflected, creating an intense blue coloration even in low-light conditions.

Developed in a similar fashion, our technology draws inspiration from nature's intricate structural coloration which harnesses the power of nanostructures to manipulate light, resulting in a coloration process without the reliance on harmful pigments or inks.



Moreover, our Nano Optic innovation integrates nanostructures with micro-scale domes, enabling dynamic coloration with added depth and movement. This unmatched level of sophistication establishes Nano Optics as the leading technology in the authentication realm.

SETTING A NEW STANDARD FOR BANKNOTE SECURITY

QUANTUM stripe is setting a new standard for security features, harnessing Authentix Nano Optic technology to deliver unparalleled protection against counterfeiting. Unlike traditional security features, QUANTUM does not use commercially available equipment and materials, opting instead for a bespoke approach that ensures exclusivity and uncompromising security.

Through intuitive authentication features such as hide and reveal, depth, and photorealism, QUANTUM guarantees easy and reliable authentication processes, empowering users to verify the authenticity of banknotes with confidence.

A standout feature of QUANTUM is its "Always-On Structural Colour" approach, which maintains consistent colours without ambiguity, even when tilted. This eliminates diffractive rainbow effects, ensuring enhanced clarity and reliability during authentication. In addition, QUANTUM can be designed to work seamlessly in a window format, visible from both sides. Also in transmission when held up to the light, these window features reveal alternate colours, adding an extra layer to the authentication process and enhancing overall security.

In essence, QUANTUM represents a paradigm shift in banknote security, leveraging cutting-edge technology and innovative design principles to safeguard against counterfeit threats. With its bespoke approach, intuitive authentication features, and advanced transmission effects, QUANTUM sets a new standard for security features, ensuring the integrity of currency in an increasingly digital and interconnected world.

TRULY INTEGRATED

"Design integration" is a phrase frequently cited in the industry, often relating to iconography, shapes and loose synergies between feature, print and substrate. However, banknote security feature integration represents more than this. It is a sophisticated fusion of design, technology, and manufacturing prowess, aimed at fortifying currency against counterfeiting while ensuring freedom of choice in specification and seamless incorporation into the banknote production process.

At its core, this integration hinges on the harmonious interaction between security features, printing techniques, and substrate composition, all meticulously orchestrated to deliver a robust and functional product. The security features must not only deter counterfeiters but also seamlessly blend with the overall aesthetic of the banknote, ensuring authenticity is instantly recognizable to the user. This can only be achieved by being able to truly represent colours, styles, imagery, and iconography across the different mediums within the banknote.

Crucially, the interaction between security features, print, and substrate is pivotal for more than aesthetic integration. The features must be compatible with various manufacturing methods—be it the substrate itself, or the banknote printing processes i.e. offset, intaglio etc. This underpinned the development process for QUANTUM to ensure the feature remained resilient under varying printing conditions and substrate characteristics. Through stringent testing protocols, these features are proven to withstand diverse environmental conditions and resist tampering, thereby instilling confidence in their use and effectiveness for the lifetime of the banknote.

SUSTAINABLE TECHNOLOGY

Authentix Nano Optic platform utilises single-layer metallized nanostructures created in a single origination process. We eliminate the need for inks, dyes and lenses which significantly reduces the material usage and reliance on harmful pigments or inks. This streamlined approach not only minimizes production variables but also contributes to environmental sustainability.

Furthermore, our production facility in Quebec, Canada is heated and powered using clean, 100% renewable hydroelectric energy, playing a crucial role in reducing the carbon footprint of our security features and aligning with environmentally friendly practices. Additionally, our security features are compatible with multiple substrates and can be applied on industry standard machinery, offering versatility in application and further contribution to issuing authorities seeking sustainable solutions.

NANO OPTICS: A NEW ERA OF SECURITY

Authentix Nano Optics technology heralds a new chapter in the fight against counterfeiting and the protection of product authenticity. With its groundbreaking approach to security features, Nano Optics sets a new standard of excellence, offering a potent combination of advanced technology, simplicity, durability, and compatibility. As we continue to refine and expand upon this innovative technology, we remain committed to empowering industries across the globe with the tools they need to safeguard their products and consumers.

AUTHENTIX

Mark Spencer
Email: info@authentix.com
Website: www.authentix.com

SENSORS

AUTHENTIX

Authentix GemVision™ Camera System and the Benefits of CDI2

FACT BOX

- The CDI2 standard enables a central bank to select a fitness sensor of their choice and provides them improved data access and direct control of note sorting.
- Central banks have too few supplier options for banknote processing. The CDI2 standard can help to address that.
- The Authentix GemVision™ Camera System is the industry's first CDI2 fitness solution. To date, Authentix has provided 25 GemVision systems to the U.S. Federal Reserve.
- The Federal Reserve's program, now in its fifth year, has confirmed that the standard is well-designed, robust and supports successful integration by multiple companies designing CDI2 compliant sorting machines and detection systems.
- The industry can benefit greatly from CDI2 and the innovative ideas and approaches it will facilitate.

WHAT IS CDI2?

Following the success of the Eurosystem's Common Detector Interface (CDI), the Eurosystem, United States Federal Reserve System (FRS), Austrian Institute of Technology, Oesterreichische Banknoten-und Sicherheitsdruck, GmbH, De Nederlandsche Bank, Lawrence Livermore National Lab, and key banknote sorting machine providers and sensor manufacturers established the Common Detector Interface 2 (CDI2) standard to; 1. enhance interoperability between sensors and banknote sorters produced by different companies, 2. reduce the development and integration time for new sensors, and 3. facilitate a market of an increased number of banknote sorter and sensor providers, an objective that is even more critical following the shrinkage in the number of companies providing central bank high speed sorters over the past few years.

While CDI1 focused on a standard sensor size and interface to facilitate the inspection of Level 3 features, CDI2 enables a central bank to mount a fitness sensor of their choice. CDI2 standardizes the fitness and authentication mechanical interface and defines the minimum image types to be used for note fitness. The new standard enhances fitness sorting and lowers the cost to manage cash by decreasing the rate of pre-mature shredding events. In addition, it provides central banks improved access to the sorting decisions and the data behind these decisions.

The CDI2 standard defines sensors as having a detector component and a processing component. While it is possible that both "parts" can be contained in a single sensor housing or pair of sensor housings, the typical configuration includes rack mounted external processing modules. A detector for authentication or narrowly defined measurement tasks consists of a Sensor and an External Evaluation Unit (EEU). The hardware associated with image capture and fitness determination consists of a Camera System and an Image Evaluation Unit (IEU). The IEU captures the requisite number and type of note images, provides these images to other sensors (as described later) and generates the fitness scores of the note; whether consisting of a collection of scores against a range of customer defined fitness categories (e.g., soil, ink wear, graffiti levels) or holistic scores that speak more broadly to the condition of the note (Fit, Unfit, Super Fit, high ink wear, medium ink wear, etc.).

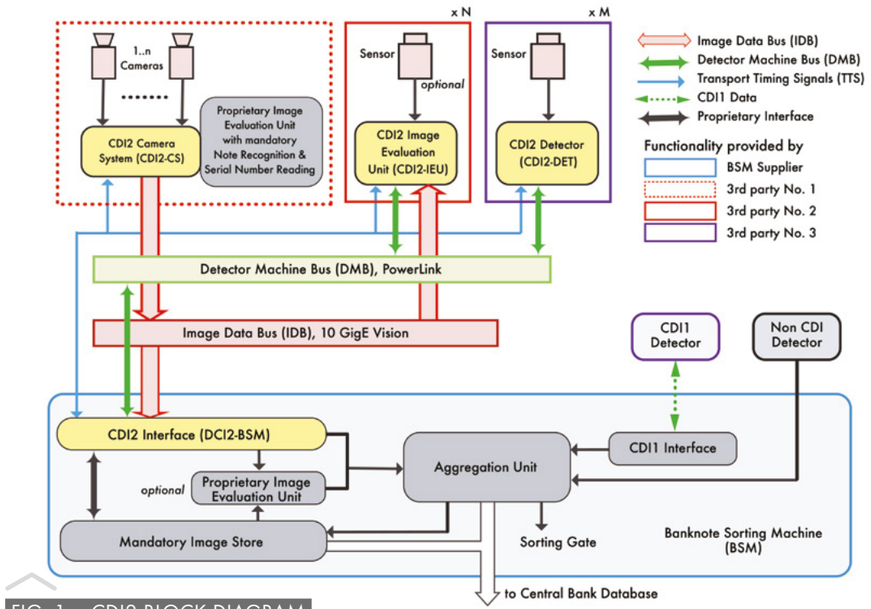


FIG. 1 – CDI2 BLOCK DIAGRAM

The block diagram in Figure 1 provides an overview of the CDI2 architecture.

CDI2 takes advantage of sensor fusion capabilities through the establishment of an Image Data Bus (IDB), highlighted in pink in Figure 1, to share images and a Data Machine Bus (DMB), highlighted in green, to share denomination and orientation results made by the Camera System and its Image Evaluation Unit combined. This allows downstream sensors which require information such as the note denomination, orientation or series to receive this information off of the DMB without having to generate the result on their own. An aggregator module also supports sensor fusion as it allows central banks to pool and weight multiple results from a collection of sensors to determine sort decisions.

BENEFITS OF CDI2

Primary benefits of CDI2 are the following:

- **Flexibility** in sensor selection allowing central banks to choose the sensors and sensor providers that fully support best practices as determined by the bank for processing banknotes.

- **Enhanced note fitness assessment** driven by the sensor fusion and directly controlled by central banks regarding note sorting decisions. This enables central banks to assess the quality, wear and authenticity of banknotes with greater accuracy and precision. This information empowers central banks to make more informed decisions regarding the circulation and withdrawal of currency, optimizing cash management strategies, maintaining the integrity of the currency supply and reducing the cost of currency management by lowering the rate of erroneous shredding of otherwise fit banknotes.

- **Ease of integration** will also help reduce the cost of currency management as it decreases the time spent by sensor companies to develop their sensors as well as the time spent by the central bank during integration and testing. The existence of the CDI2 standard will lower the barriers for new companies to enter the banknote sensor market and may lead to healthier competition and increased value to central banks.

- **Increased note security** can be realized by making it easier for more companies to develop currency sensors, providing central banks a wider choice of innovative security features and authentication sensors. Through this heightened innovation environment, new and improved authentication concepts will increase note security. As a result, the CDI2 standard has not only disaggregated the sensor from the sorting machine, but also disaggregated what was previously viewed as "the fitness sensor" into a Camera System and a separate Image Evaluation Unit. This means that entities with novel approaches to inspect a banknote or the analysis of the CDI2 images can choose where to focus. Instead of providing a complete Camera System and IEU solution, they could target one or the other, either providing a new Camera System hardware design or connecting a device to the data buses to process the images that are shared with all sensors. This additional utility could replace an IEU or augment its results with additional image processing results, potentially bolstering fitness results and, authentication results.

CDI2 Required Image Types	Authentix GemVision™ Image Types
Red, Green and Blue reflectance images (200 µm resolution)	Red, Green and Blue reflectance images (200 µm resolution)
IR reflectance image (200 µm resolution)	IR reflectance image (200 µm resolution)
-	Grey scale visible reflectance image (50 µm resolution)
-	Red, Green and Blue reflectance images (100 µm resolution)
-	IR image (50 µm resolution)
-	Full color reflectance image with grazing angle illumination.
-	Light scattering generated transmission image
-	Shadow mask transmission image

TABLE 1 illustrates the broader array of image types providing new views onto the quality of the note and its overt security features. GemVision is the third fitness sensor platform developed by Authentix. The capabilities of the first two sensors, one of which was a single sensor pair design for paper-based notes and the other a dual sensor pair design targeting the distinctive challenges of determining fitness of polymer notes with large clear windows and over features, have been combined into a single sensor pair with increased capabilities.

GEMVISION™ CAMERA SYSTEM

Authentix, along with its sensor development partner Boulder Imaging, has developed for the Federal Reserve a CDI2 Camera System and Fitness solution that meets the CDI2 requirements for a Camera System and provides additional capabilities as highlighted in the table 1 above.

IMAGE TYPES / SUPPORTING FITNESS MEASUREMENTS

High resolution (100 µm) full color images shown to the right are excerpts from an $100 USD image captured at note speeds exceeding 10 meters per second (>40 notes/sec) highlighting the high resolution capabilities that allow a high accuracy (less than 1 misread in 10,000 notes) of small text items such as the series year and intaglio plate letters and numbers. Balanced illumination is created by a pair of LED illuminators each angled by the same amount off of the plane perpendicular to the note motion.

FIG. 2 – HIGH RESOLUTION IMAGE EXCERPTS CREATED WITH BALANCED ILLUMINATION

High resolution (50 µm) IR image
The high-resolution image below is used to confirm the IR transparency of inks, the presence of windowed threads and resolve serial numbers and other text features.

FIG. 3 – HIGH RESOLUTION IMAGE FROM IR ILLUMINATION

Balanced vs. Asymmetric Illumination
By capturing full color reflectance images using both balanced as well as asymmetric illumination, GemVision confirms the presence and activity of overt features as shown with the stunning image of the hologram on the New Zealand $10 as shown in Figure 4. This imaging approach can also determine if the quality of the overt feature has degraded over time and factor this information into the note fitness decision. An example of this is shown in Figure 5 where the degradation of the foil performance has been clearly identified.

FIG. 4 – CHANGE IN APPEARANCE OF THE HOLOGRAPHIC THREAD UNDER TWO DIFFERENT ILLUMINATION CONDITIONS

FIG. 5 – BALANCED AND ASYMMETRIC ILLUMINATION IMAGE VIEWS HIGHLIGHTING THE DEGRADATION IN THE OPTICAL ACTIVITY OF THE HOLOGRAPHIC FOIL

These two image views are also used to determine the degree of crumples and creasing on the note as shown in Figure 6. In the image on the left, the balanced illumination avoids creating shadows on the note and provides a highly accurate assessment of the note color and ink wear. However, the presence of shadows is valuable information which can be used to determine the fitness of the note or the fitness of tactile features provided for the visually impaired. The image on the right is generated by asymmetric illumination and the presence of a large crease is clearly revealed.

FIG. 6 – USE OF BALANCED (LEFT) AND ASYMMETRIC (RIGHT) ILLUMINATION TO DETECT CREASES AND CRUMPLING

Scattering and shadow mask transmission images

GemVision relies upon two types of scattering images to assess the fitness and authenticity of a banknote. A scattering transmission image is captured by the "back side" sensor housing while the balanced reflection image is captured on the "front side". As the illumination is arriving on the note at an angle, the transmission image is created by light that is scattered forward into the collection optics as shown in Figure 7. From these images GemVision confirms the presence of embedded security threads, paper "bridges" on windowed threads.

FIG. 7 – SCATTERING TRANSMISSION IMAGE

A shadow mask image is also collected by illumination that is perpendicular to the note. From these images GemVision assesses the note size and dimensions, identifies missing material due to holes and tears and assesses the condition and authenticity of see through features such as holographic foils as depicted in the image segments displayed in Figure 8.

FUTURE OF CDI2

Since the release of the CDI2 specification in 2016, the standard has undergone numerous upgrades and revisions. Many of these improvements have been identified as parties began to design CDI2 components and integrate them into the first CDI2 sorting machine solution as part of the Federal Reserve's tender to upgrade their cash sorting environment. This program, which is in its fifth year, has confirmed that the standard is well-designed, robust and supports successful integration by multiple companies designing CDI2 compliant sorting machines and detection systems.

Central banks have too few options with respect to sorting machine and sensor providers. This situation has only become worse with Cash

FIG. 8 – IMAGE SEGMENTS OF HOLOGRAPHIC FOILS AS SEEN BY THE SHADOW MASK TRANSMISSION VIEW OF GEMVISION

Processing Solutions (CPS) recently exiting the banknote sorting machine manufacturing industry. While it is uncertain if new providers will enter the banknote sorting machine business offering a full suite of fitness and authentication sensors, the CDI2 standard will make it easier to envision such new entrants coming into the industry.

Central banks are facing a challenging cash processing environment characterized by increasing capabilities by counterfeiters, decreasing supplier options, uncertainties regarding the continued growth of banknotes, and increased emphasis on decreasing the cost and environmental impact of cash. Broad adoption of CDI2 can serve to bring increased competition into the industry to better assist central banks in addressing these challenges.

Today, the CDI2 standard is being used by one central bank. The industry will benefit greatly if this becomes a true industry standard adopted by many central banks and consequently introducing new and innovative ideas and approaches to the market.

AUTHENTIX

Mr. Tim Driscoll, Ph.D.
CTO Authentix
Email: timdriscoll@authentix.com
Website: www.authentix.com

FACT BOX OVERVIEW

| 62

AUTHENTIX

(Features)

www.authentix.com

- **Counterfeit Resilience:** Our proprietary algorithms and specialized manufacturing techniques establish a new standard of security, making reverse engineering virtually impossible.
- **Ease of Authentication:** Our features are intuitive and simple, developed with decades of anti-counterfeit expertise.
- **Durability:** Tested by third parties, our technology ensures longevity and integrity, even in challenging environments.
- **Integration:** QUANTUM™ is compatible and proven with paper, polymer and mixed substrates. While seamlessly integrating into existing manufacturing workflows.
- **Innovation:** Positioned at the forefront of security technology, Nano Optics represents the dawn of a new era in authentication.

| 108

AUTHENTIX

(Sensors)

www.authentix.com

- The CDI2 standard enables a central bank to select a fitness sensor of their choice and provides them improved data access and direct control of note sorting.
- Central banks have too few supplier options for banknote processing. The CDI2 standard can help to address that.
- The Authentix GemVision™ Camera System is the industry's first CDI2 fitness solution. To date, Authentix has provided 25 GemVision systems to the U.S. Federal Reserve.
- The Federal Reserve's program, now in its fifth year, has confirmed that the standard is well-designed, robust and supports successful integration by multiple companies designing CDI2 compliant sorting machines and detection systems.
- The industry can benefit greatly from CDI2 and the innovative ideas and approaches it will facilitate.

| 164

BANCO DE MÉXICO

www.banxico.org.mx

- Sustainability has become a relevant topic for all industries and sectors, among which Central Banks and Monetary Authorities are no exception, especially as their role in addressing risks associated with climate change and supporting the development of green finance is more frequently discussed.
- Banco de México understands the importance of its role in society by promoting the conservation and protection of the environment as a legacy for future generations.
- The General Directorate of Currency Issuance, along with the National Autonomous University of Mexico initiated the project "Environmental performance evaluation of the currency provision macroprocess" in 2013, from which relevant conclusions were drawn: the need to increase banknote durability and to develop alternatives for banknotes waste disposal.
- As part of the development process for the G series of Mexican banknotes, the information obtained through this project allowed Banco de México to generate an action plan to attend these opportunities.

| 182

BANQUE DE FRANCE

www.banque-france.fr

- 8 km by car is the annual environmental impact of banknote payments per euro area citizen; it remains low when using cotton as a substrate.
- The Banque de France's low-carbon strategy aims to reduce its Green House Gas (GHG) emissions by 15% by 2024 compared with 2019, and it has far exceeded this target, cutting its emissions by 23.6% between 2019 and 2022.
- Banque de France and EuropaFi are delivering high security paper and banknotes in more than 30 countries.
- 100% of banknotes shredded by sorting machines are currently incinerated with energy recovery. Through circular economy initiatives, Banque de France is developing new valorisation chains.
- Cash activities, which include the manufacturing of banknotes as well as the circulation, are industrial in nature, as opposed to its other activities, which are tertiary. As a result, they account for nearly half the Bank's total GHG emissions.
- Improving and reducing a banknote's environmental footprint require working on all its components: raw materials and substrates, paper production and printing, banknotes durability, distribution, end of banknote's life.

| 148

BLENDPAPER SECURITY

www.blendpaper.com.br

- A century-old company that blends tradition and inventiveness, developing and producing special paper for increasingly demanding markets. It is among the first paper production mills in Brazil still in operation and is the only one in Latin America with the know-how and technology to produce banknote paper.
- In 2022, the company was acquired by a Brazilian group of investors, culminating in the birth of Blendpaper. BP Security is the Blendpaper brand specializing in the development of solutions for the banknote paper and high-security paper markets.
- Development of initiatives in line with the environment, in which it stands out the project that allows the utilization of cellulose from banknote that are no longer in circulation.
- Modern process for developing new technologies applied to banknote papers, in which it stands out the development of new watermarks, in which the process is fully internalized by the company from the drawing of the initial artwork to the automated manufacturing of the mould.

| 206

BOBST

www.bobst.com

- The international converting equipment specialist BOBST has introduced new features and tools which transform hologram application and quality control in the converting industry.
- The hot transfer stamper NOVAFOIL 106 with its unique platen, dedicated to hot stamping transfer, can now be equipped with up to 10 independent modules, specifically designed for hologram applications. Combined with the no-sheet-edge contact ACCUREGISTER, hologram application reaches new levels of precision and production efficiency.
- To ensure a thorough and traceable quality control, the Digital Inspection Table offers off-line quality checks relying on digital data. From pre-press to finished product, the tool ensures precision and consistency, while supporting continuous quality improvement through easily accessible reports and tool-machine connectivity.
- With the BOBST Smartphone Microscope and a brand-new 3D microstructure scanning tool, visual and structural details can be checked quickly and with precision. These tools enable quality control of security features invisible to the human eye.