Solutions to sort, track & protect your products & materials with Sort4Circle®, TrackByStars®, BRANDPROOF® and POLTAG®

Für Netzwerk “Zukunft Kunststoff”, 20.05.2026



POLYSECURE

Polysecure – Building Material Intelligence

We **sort, track & protect** your products & materials.
Turning materials into data. Turning waste into value.



- 🌍 *Based in Freiburg, Germany, ~2000 sqm pilot sorting facility, chemical production, labs etc.*
- 👥 Interdisciplinary team of *~36 across chemistry, physics, engineering, software & AI*
- 🧪 *10+ years of focused & strategic R&D*
- 🔬 End-to-end technology: from fraud-proof tracking → to material identity → to precision sorting

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One Platform – Four Technologies

SORTING

Sort4Circle®

Cost-efficient & precise single-stage sorting technology for plastics & other materials



Tracking

TrackByStars®

Robust & forgery-proof tracking of individual products (Digital Product Passports, Anti-Counterfeiting)



BRANDPROOF®

Mobile product & material authentication (Anti-Counterfeiting)



POLTAG®

Material tracking & authentication by sequence-defined oligomers (Digital Material Passport, Anti-Counterfeiting)



Fluorescent Markers

Oligomers

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Spotlight on fluorescent markers…

Leveraging their diverse **physical characteristics** to power our technology platform

Emission Spectrum

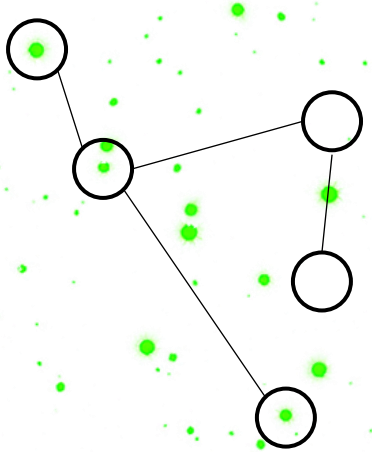


Sort4Circle® +

Tracer-Based Sorting

Sorting

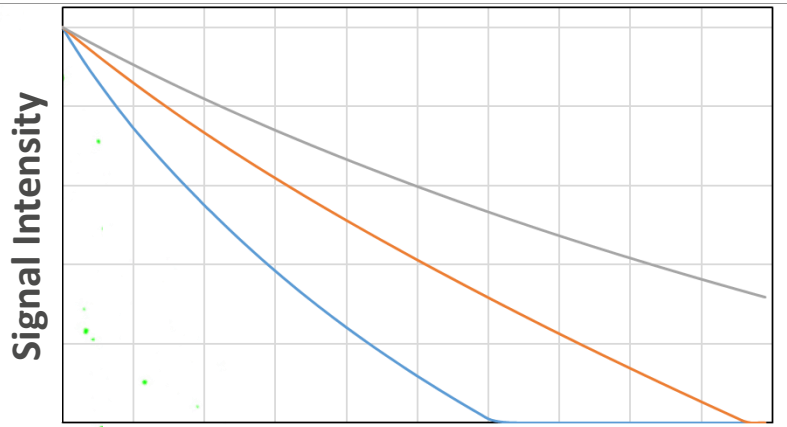
Spatial Particle Distribution



TrackByStars®

Identification

Dynamic Emission Behavior



BRANDPROOF®

Authentication

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Sort4Circle®

First cost-efficient, technology-open and precise sorting technology for plastics and other materials



Looking at today’s process chain of plastic recycling

Only 26,9% of collected plastics can be identified & sorted well enough so that they can be sent to a recycler. Only 12,6% of new plastic products are based on recycled content.

Circular Economy of plastics in EU27+3, 2022 (Plastics Europe)



A: Recyclate use rate **12,6 %**	B: Recycling Rate **21,1 %**	C: Sent to recycling rate **~ 26,9 %**

Packaging | Building & Construction | Automotive | Electrical & Electronics | Agriculture | Houseware & Leisure & Sports | Others

Independent of the subsequent recycling technology, how could better sorting improve the circularity?

C: (26,9%) Low “sent-to-recycling rate” (=low sorting yield):
-> Identify and sort more items into more and better specified fractions without increasing impurity levels

B: Significant process losses at recycler:
-> Improve the purity of sorted fractions before they enter recycling…

A: Poor recyclate quality to prevent higher recyclate use rates
-> Improve the specification, number and purity of sorted fractions

Conclusion: Better sorting is the core measure to improve circularity!

Comment: Better sorting and Design-for-Recycling (D4R) complement each other!

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Looking closer at today’s (plastic) sorting technology

Multi-step sorting with open NIR sorters and air nozzles has obvious technical and economic drawbacks



Detection drawbacks:

NIR unable to identify food / nonfood, multilayer, polymer subclasses and specifications

NIR alone to immanently produce **false positives**

AI unable to reliably identify non printed / flexible / deformed / shredded objects

Separation / sorting drawbacks:

Air nozzles and overloaded conveyor belts to produce **10 - 20% error**

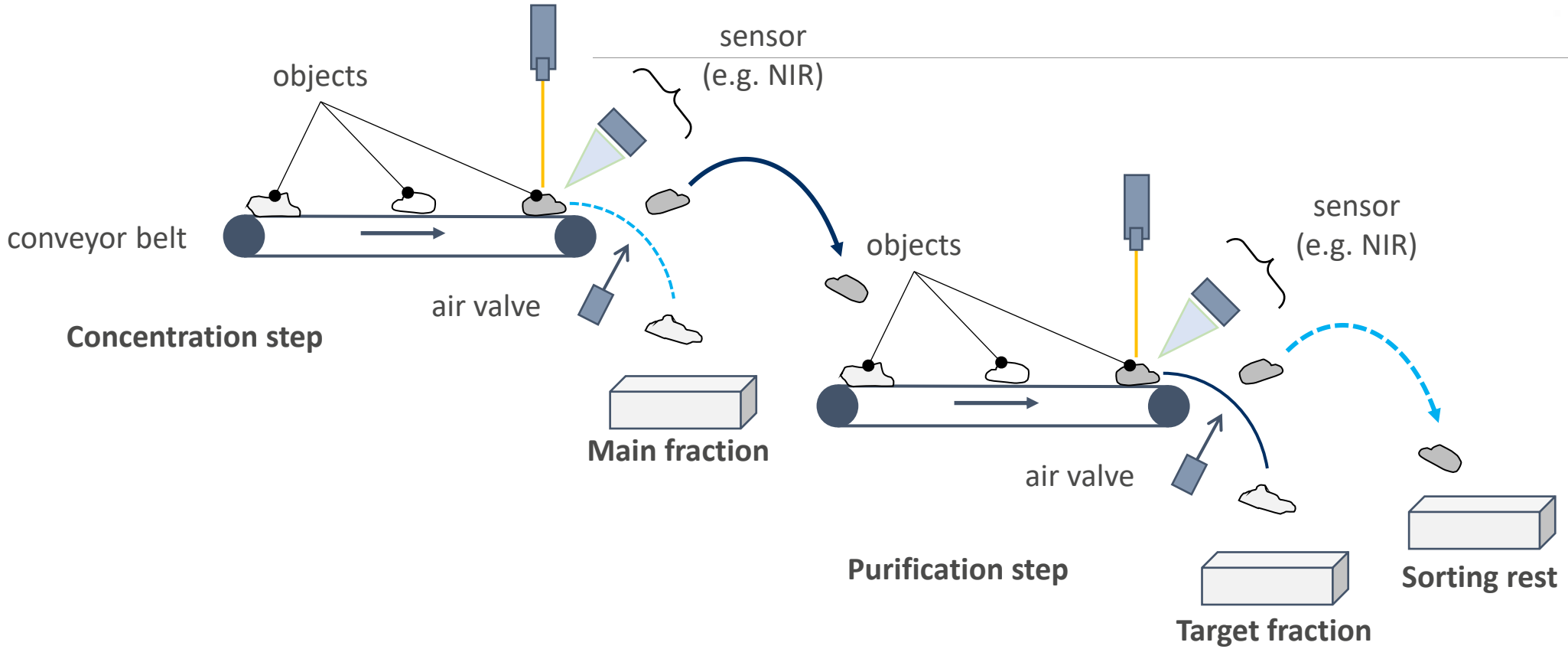
Economic drawback:

Air nozzles can only blow out one fraction -> sorting steps and **costs increase significantly with number of sorting fractions!**

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Multi-step sorting requires two sorting steps per fraction

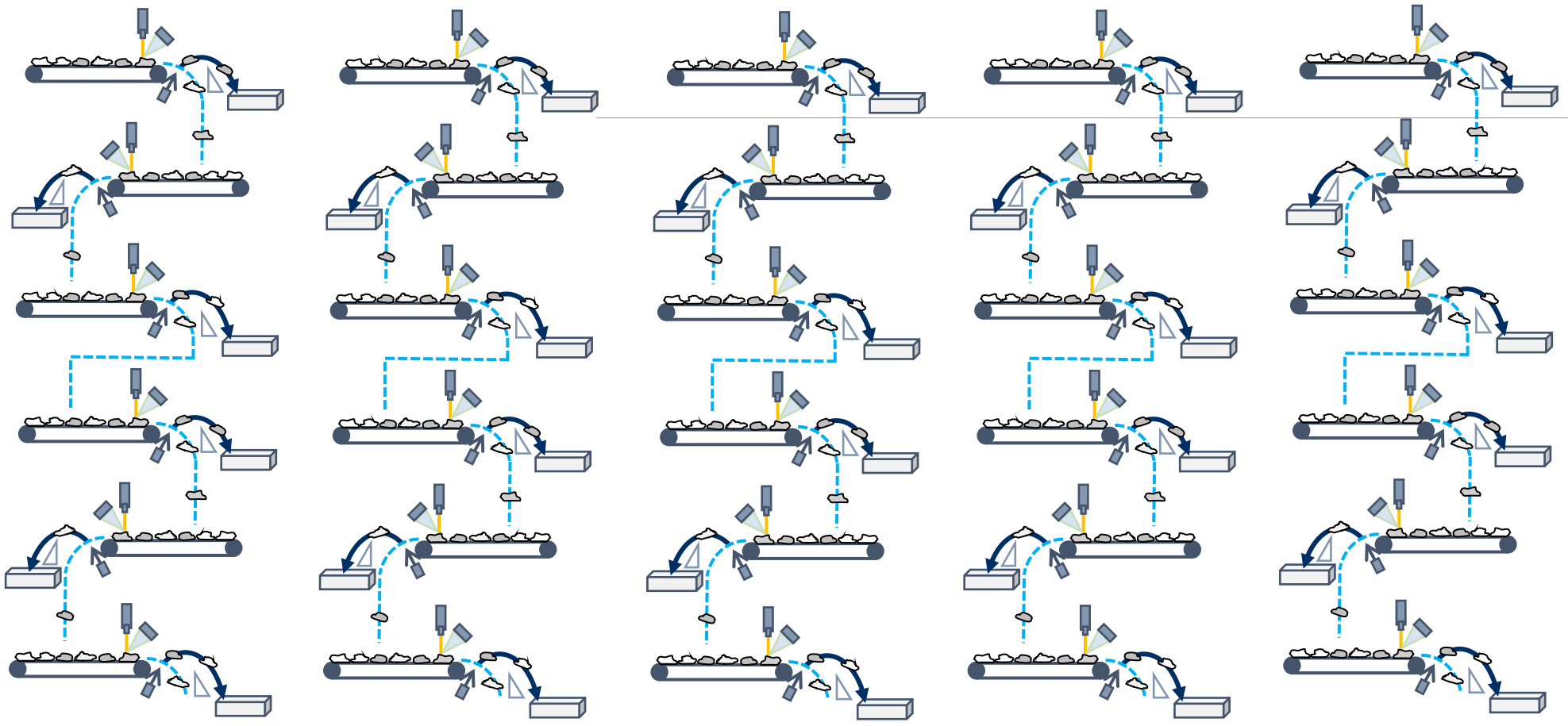
The need for two sorting steps (concentration and subsequent purification) is the result of the drawbacks of current NIR sorters with air nozzles



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15 sorting fractions require 30 sorting steps today

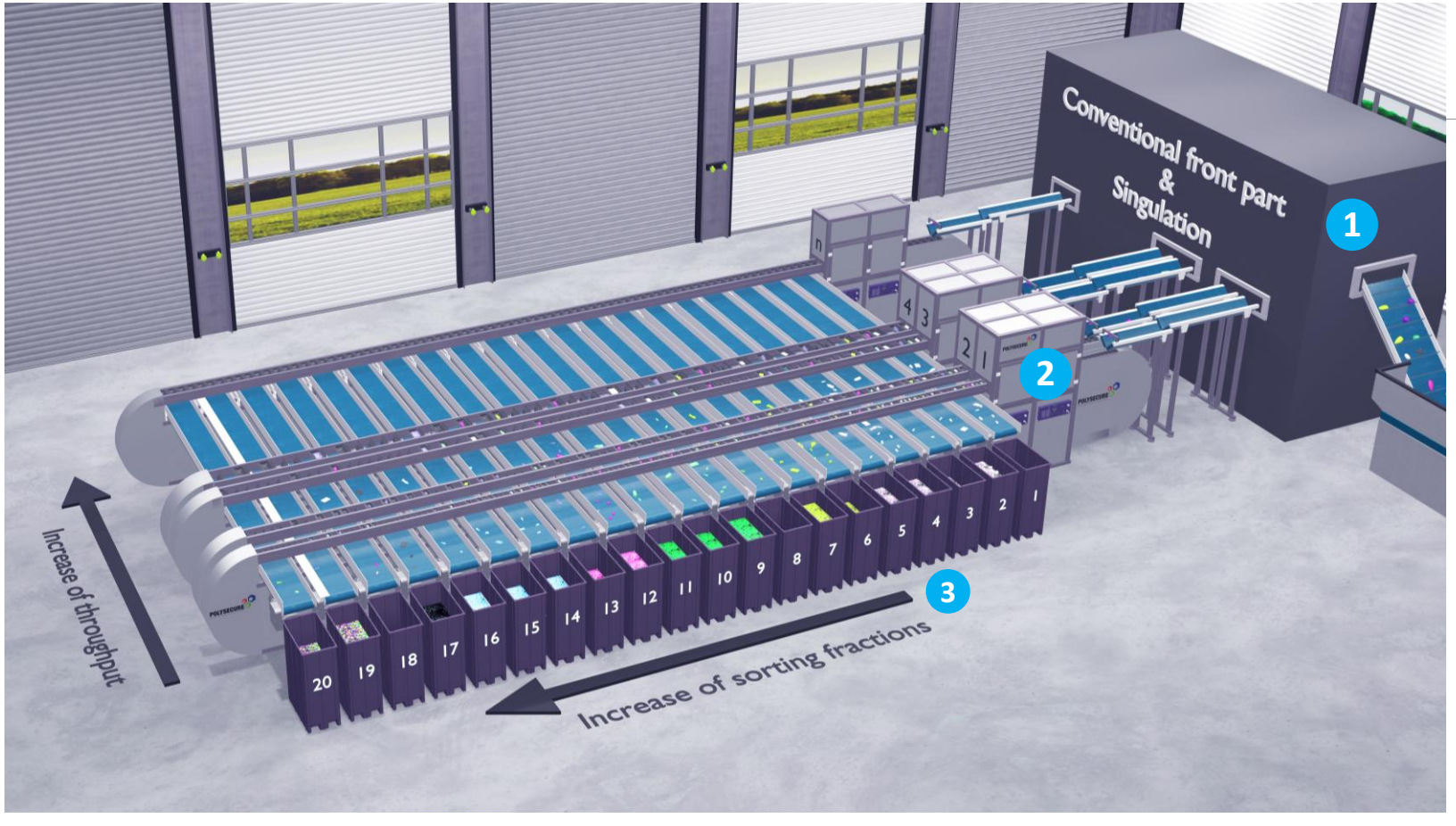
Can multi-step sorting with open NIR sorters and air nozzles be an efficient sorting technology for the Circular Economy of plastics and other material streams?



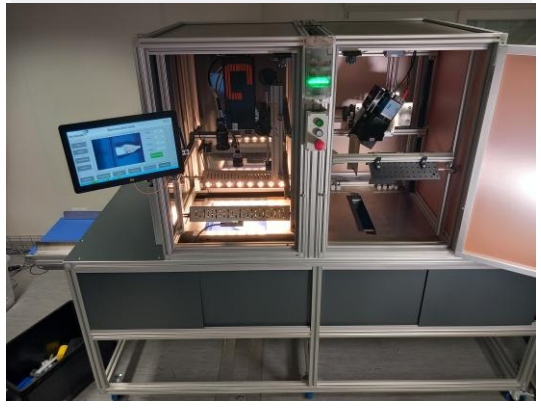
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Sort4Circle® - created to overcome current challenges

First sorting technology for waste streams with sophisticated in-line single-object material analysis and sorting into as many fractions as needed without increasing process costs



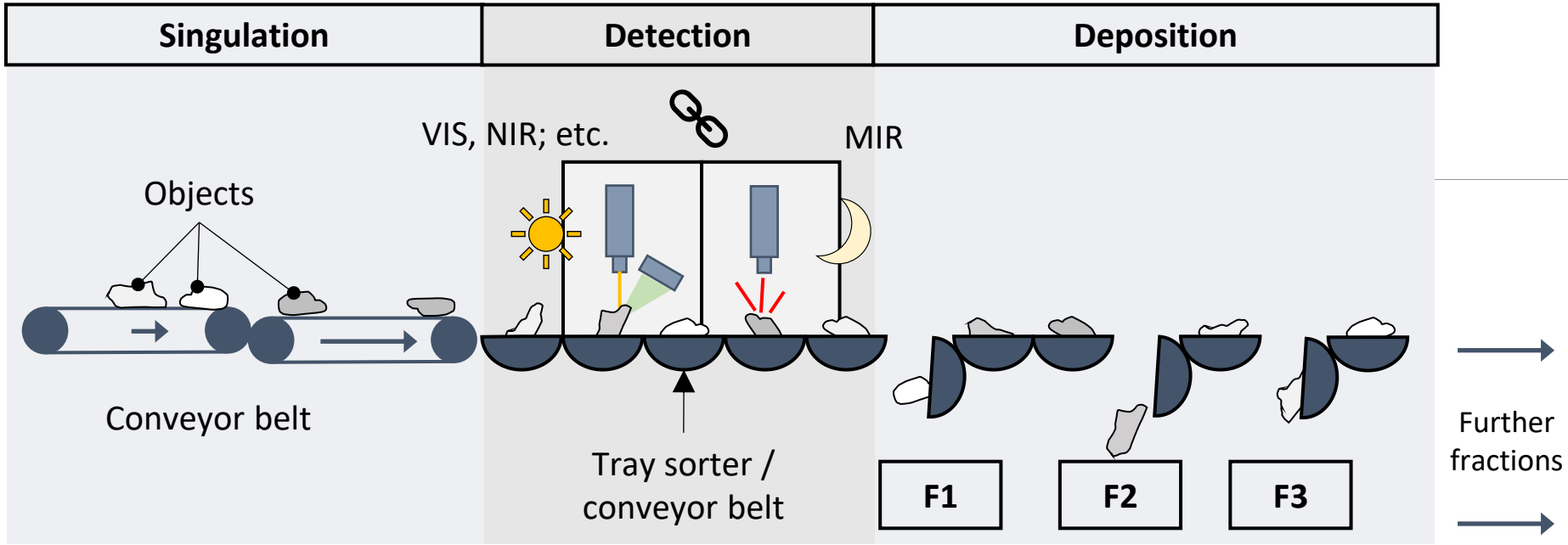
1. Automated **singulation** and placement of all items onto a single-track conveyor system which passes a few shielded measurement chambers at high throughput. Object **detection** by subsequent VIS/color, VIS/image (AI-enhanced), NIR, MIR & further measurements. Errorless **sorting** into as many target fractions as needed.



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The sorting process

The Sort4Circle® approach to sorting objects



- **Lower sorting costs** than multi-step sorting as from 4 - 8 sorting fractions on
- Enables **large number of fractions** without exploding sorting costs

- Provides more flexibility and **scalability in terms of throughput**, number and definition of fractions
- **High yield and purity of sorted fractions feasible**
  → higher recycling rates

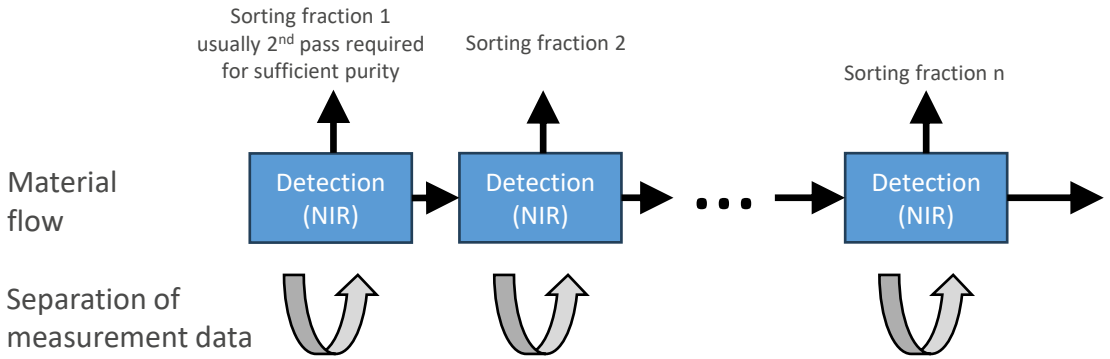
- Employs all relevant detection technologies
  → **technology-open**

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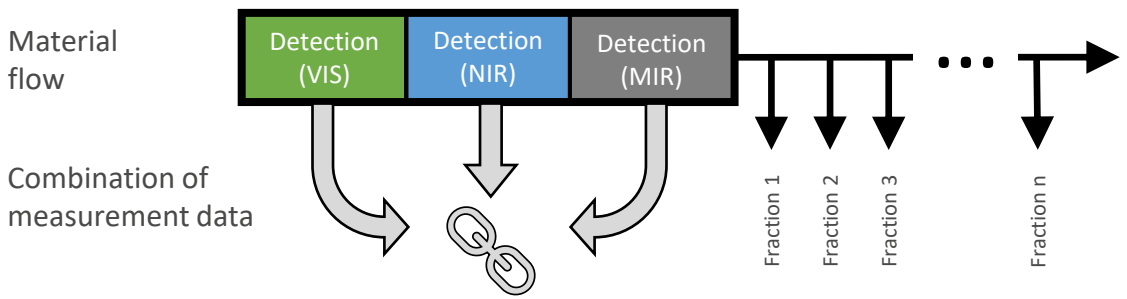
Sort4Circle® - singulation / sorting approach

Innovation & paradigm shift #1: singulate and place all material chunks and waste articles into a single-track conveyor system off which items can be displaced without error into specified outputs

Conventional multi-step sorting:



Sort4Circle® single-step sorting:



Advantages of Sort4Circle®

Cost-efficiency

Almost no increase of sorting costs with number of sorting fractions; typically lower sorting costs than multi-step sorting as from ~4 fractions on, despite significantly better measurement techniques

High yield and purity

Single-object measurements in small, separated and shielded detection chambers together with the sorting into as many fractions as needed provides better material identification, much higher
sorting yield and much higher purity of sorted fractions

Technology openness

Each sorting object is measured with every relevant measurement technology. Additional detection technologies can be efficiently retrofitted.

Flexibility and scalability

Number of sorting fractions can be easily increased without having to change the setup. Capacity can be easily increased by adding more parallel sorting lines.

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Sort4Circle® - detection / measurement approach

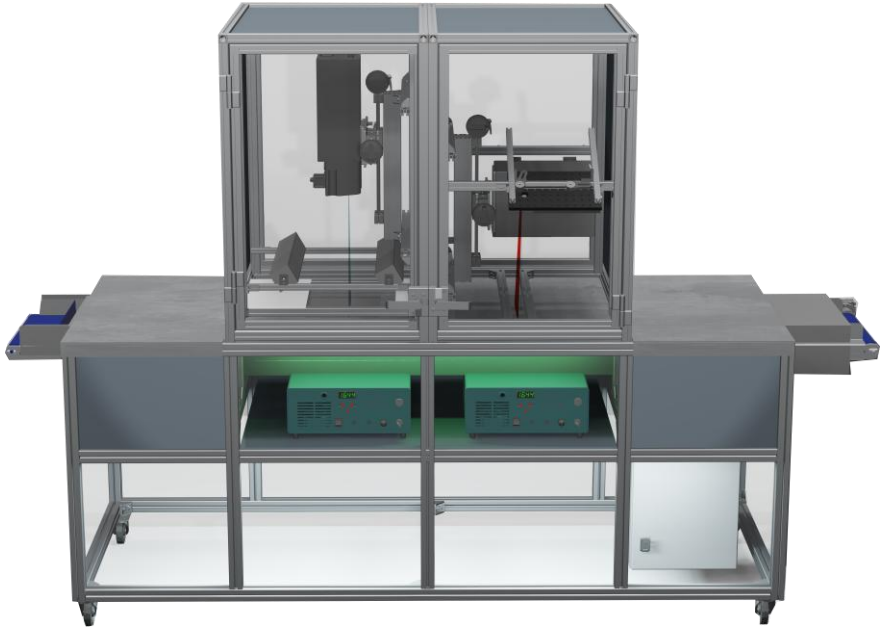
Innovation & paradigm shift #2: Use all relevant & fast (< 10ms) measurement techniques that are needed to identify polymer type & specification, color, application (e.g. food contact) and more

Combined and technology-open detection

Information 1	+	Information 2	+	Information 3	+	Information 4	+	Information 5
color measurement, image (AI-assisted) *VIS camera*		polymer type (without carbon black) NIR spectrometer		polymer specification (e.g. PP with glass fiber) Tracer-Based-Sorting		polymer type (with carbon black) MIR spectrometer		specific additives (e.g. PFAS, flame retardants) LIBS

Singulation & placement onto single-track conveyor

manually or automated



Assignment & sorting to as many fractions as needed @ stable process costs

automated

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Sort4Circle® - What formats and materials can we sort?

Automatization, handling and detection of the Sort4Circle process can be adopted and optimized to many formats and materials

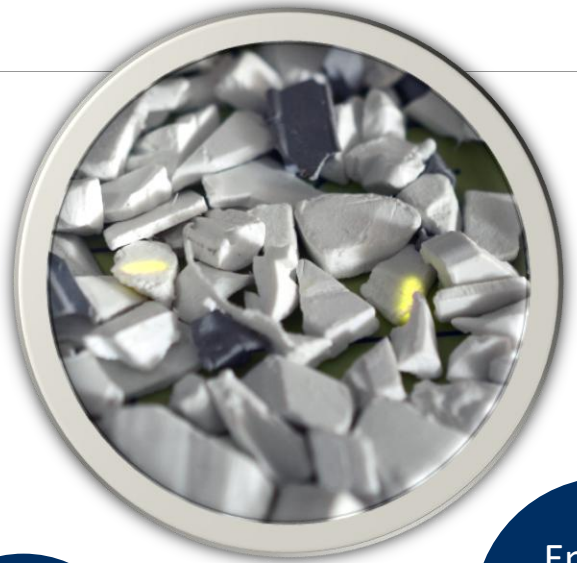
- Marker as option to improve sorting



shredded flakes > 10 mm

articles (e.g. packaging)

large parts up to 1 m



Inhouse Recycling

End-of-Life Recycling



all plastics, composites, rubber

wood, other biomaterials, glass, metals and more

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Sort4Circle® pilot line for shredded (technical) plastics

Singulation, handling, combined detection and sorting to multiple fractions



Achieved figures of merit:

> 98% pure polymer fractions by NIR (PE, PP, PA, PC, PEEK, PET, POM, ABS, PS, PVC, PVDF): higher purity than conventional systems due to better measurement conditions

> 99,5% pure fractions by fluorescent marker and color -> enables definition & sorting into specifications

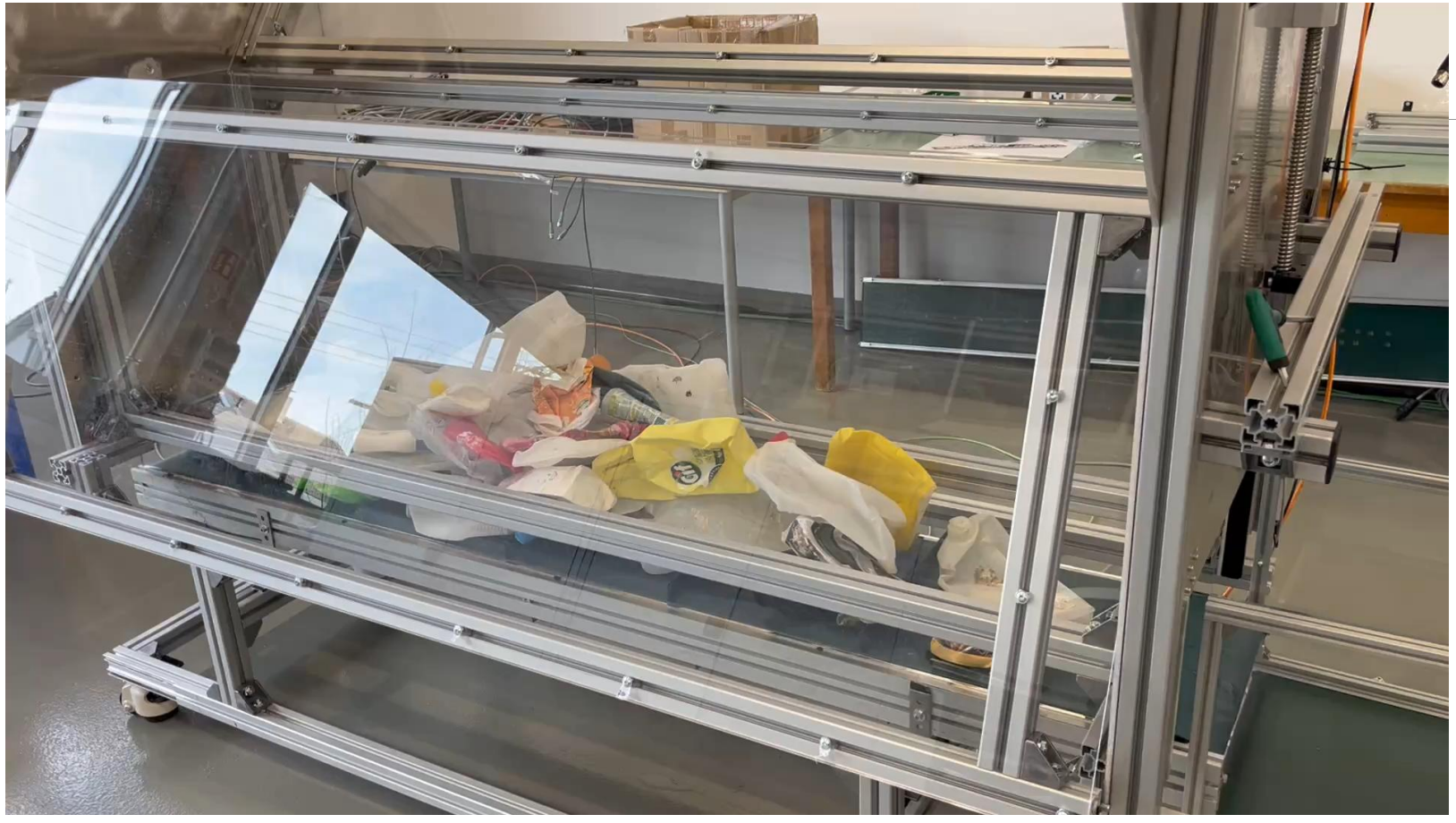
Effective 2,6 objects/second achieved

3-4 objects/second feasible with further R&D

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Sort4Circle® pilot line for rigid packaging

Singulation, handling, sorting into as many outputs / fractions as needed at same sorting costs



Achieved figures of merit:

80% of objects singulated

3 objects / second

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Impressions from current project (March 2026)

Large part sorter for 11 polymer and numerous color fractions (RAL)



Features:

Identification of 11 polymers without carbon black creating >99,5% pure fractions (NIR)

Identification of 3 polymers with carbon black (MIR)

Precise color measurement (RAL)

Optionally detection of fluorescent markers

Manual & automated feed-in & -out

Part size up to 800 x 800 x 150 mm^3

Cubic parts and round rods

Throughput with manual feed: up to 1200 parts/hour

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Spotlight on fluorescent markers…

… as part of our technology platform: They enable efficient detection!

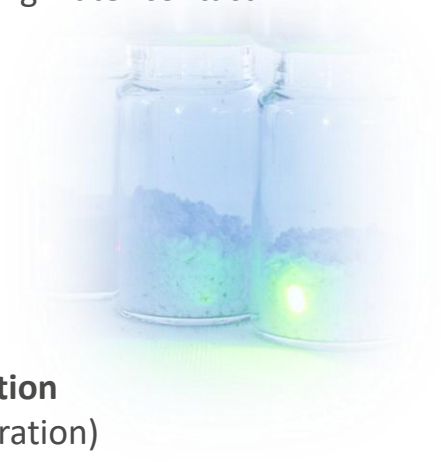
Crystalline particles with strong, characteristic fluorescence

High thermal, physical and chemical **stability** and **low solubility**

Good **biocompatibility**, compliance with food and drinking water contact

Robustly available over many use cycles and years

Fast and **reliable detection** (even at very low concentration)



Industrial companies have successfully marked ~ **200,000 tons** of their products with Polysecure markers.

Compliance with **EU food contact regulations** has been achieved in Q4 2023

FDA approval for food contact applications has been granted in Q2 2024

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Why fluorescent markers?

Fluorescence is the best physics to reliably detect fast moving items

Fluorescence is the only process by which items can move rapidly and without alignment (through an excitation field) and respond with a radially symmetric own emission of a distinct optical signal.

“Pure” signal detection, practically no computation and no false positives

Experiments on the detection rate of marked PP bottles (10 ppm marker)

Marker code	**Correct-positive**	False-positive	Rejected	**Purity**
MB-A	**99,8%**	0%	0,2%	**100%**
MB-B	**100,0%**	0%	0%	**100%**

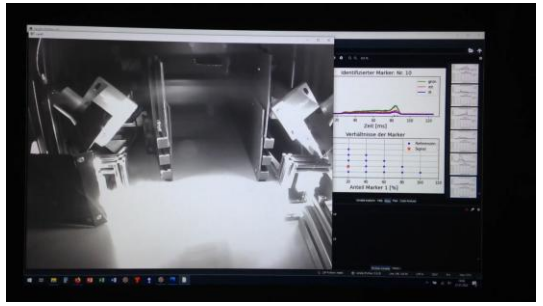
Detection is practically **independent from speed, deformation, orientation**

Fast detection (< 10ms) due to absence of computation and optical regime

Usable for **many life cycles** (marker within material) or **only for one cycle** (marker via print or label)



Packaging with sorting marker in bulk and on pack (via print)

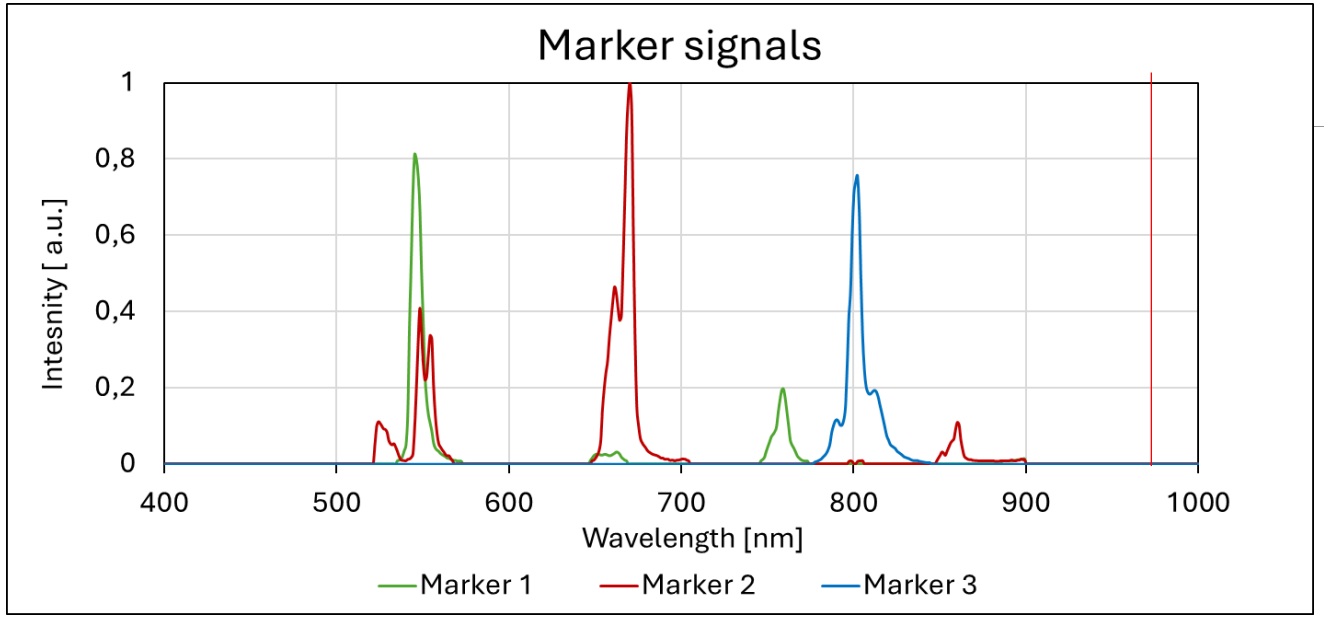


Marker detection within sorting demonstrator

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The distinguishing feature

Marker: The basic principle of code generation



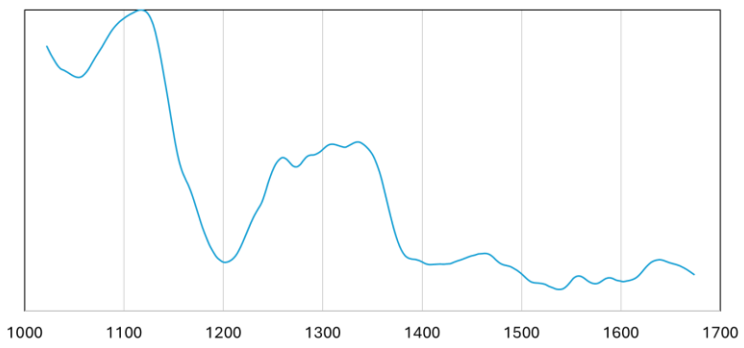
Code	M1	M2	M3
1	100	0	0
2	80	20	0
3	60	40	0
4	40	60	0
5	20	80	0
6	0	100	0
7	80	0	20
8	60	20	20
9	40	40	20
10	20	60	20
11	0	80	20
12	60	0	40
13	40	20	40
14	20	40	40
15	0	60	40
16	40	0	60
17	20	20	60
18	0	40	60
19	20	0	80
20	0	20	80
21	0	0	100

Mixing markers in **predefined ratios** produces fluorescence codes which can be used as highly efficient and reliable **sorting codes**

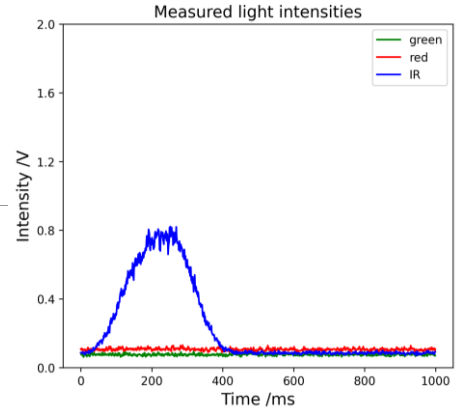
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The distinguishing feature

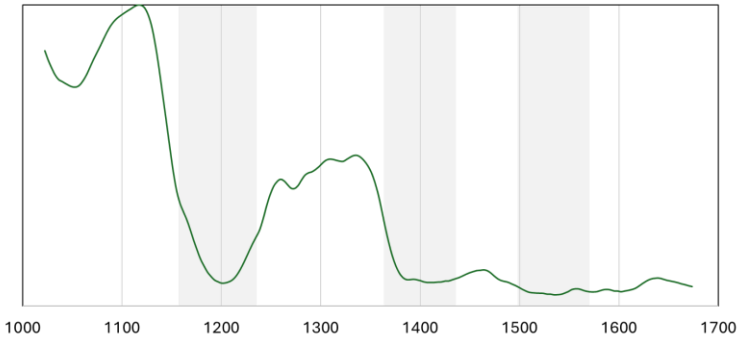
Application



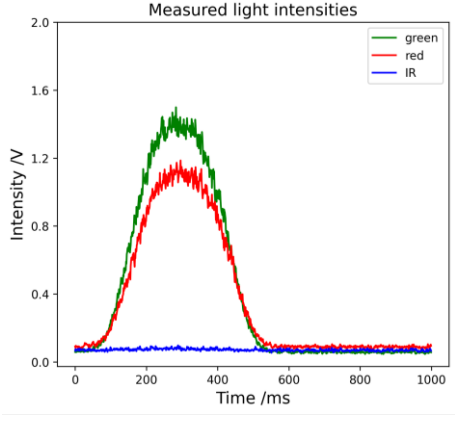
PA +



100% Marker 3: **Code 21** = **PA6G**



PA +



60% Marker 1
40% Marker 2
Code 3 = **PA6.6**

Marker detection allows **differentiation within plastic fractions** (e.g., PA6 from PA6.6, fillers, etc.) and complements existing detection methods

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Competitive landscape

Sort4Circle® has relevant USPs

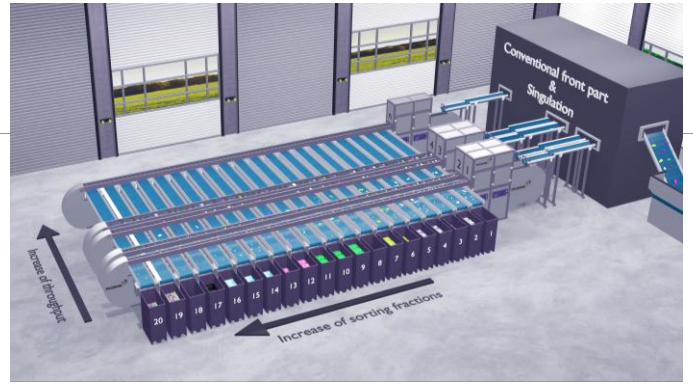
Capability level of proposed technology

	NIR-Based Sorting	AI-Based Sorting	Watermarks-Based-Sorting	Tracer-Based-Sorting	SORT4CIRCLE®
Sorting criteria	**Absorption of polymer**	**Artwork recognition**	**Micro structures (print or surface)**	**Characteristic emission spectrum**	**NIR, color, MIR, AI, FM, LIBS, watermark**
Sorting mechanism	**Step by step, air nozzles, open sorters, limited measurement technology, limited fractions**				**Single step – flexible fractions**
Enabling circular economy: Ability to adopt and optimize sorting to waste fractions needed from CE point of view					
Reliability of the sorting: high detection rates and high purities of sorted fractions					
Technology-openness: Works with all relevant detection technologies -> future-proof investment					
Feasibility for all formats: small, large, flexible, printed, not printed, black, polymer / fiber structures and flakes					
Design-for-Recycling (D4R): Reduction of ink and further packaging innovation					
Scalability and **flexibility:** Sorting of numerous fractions relevant for the market and the Circular Economy					

Summary Sort4Circle®

Cost-efficient & precise single-stage sorting technology for plastics & other materials

- **Single-stage** sorting into purer, better specified and more fractions without that sorting costs explode with the number of fractions and desired sorting purities
- **Sorting costs** range from 20 to 200 Euro per ton, depend mostly on the average weight of sorting items and are lower than a multi-step process as from 4-6 fractions on
- Shielded detection system which integrates all relevant measurement techniques: e.g. NIR, MIR, image/AI, color, LIBS, XRF, fluorescence -> Insofar Sort4Circle® provides **technology-open** sorting so that stakeholders do not need to agree on specific sorting features.
- Sort4Circle® works without and with fluorescent markers. Fluorescent markers are an ideal solution for **closed loops**, high sorting purities **(>99%)** and to define specific material fractions.
- As single-step sorting technology with a shielded detector, Sort4Circle® can be extended to use 360° image recognition to read **Digital Product Pass** (DPP) codes and sort by them.





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