

Supporting information

1. Angle distribution of Mie scattering:

$$I(\theta) \propto \left| \frac{2n+1}{n(n+1)} \sum_{m=1}^n (2m+1) i^m a_m P_m^1(\cos \theta) \right|^2 \quad (S1)$$

θ : Scattering angle;

n : Number of terms in the expansion of Bessel functions, and it is related to the size of particles and the wavelength of light;

a_m : Coefficient related to particle refractive index;

$P_m^1(\cos \theta)$: First type of joint Legendre polynomial.

2. Spectrum data augmentation formula:

$$NewValue = RawValue + (RawValue \times random(-0.02,0.02)) \quad (S2)$$

NewValue: Spectrum value after augmentation;

RawValue: Raw spectrum value;

random(-0.02,0.02): Random function.

3. z-score normalization:

$$x_j^{(i)} = \frac{x_j^{(i)} - \mu_j}{\sigma_j} \quad (S3)$$

$$\mu_j = \frac{1}{m} \sum_{i=0}^{m-1} x_j^{(i)} \quad (S4)$$

$$\sigma_j^2 = \frac{1}{m} \sum_{i=0}^{m-1} (x_j^{(i)} - \mu_j)^2 \quad (S5)$$

$$y_i' = \frac{y_i - y_{\min}}{y_{\max} - y_{\min}} \quad (S6)$$

j : The j -th characteristic of the spectrum;

μ_j : The mean of all features of the feature dimension;

σ_j : The standard deviation of all features of the feature dimension;

y_i : Represents the signal strength corresponding to the i-th angular position in each ray of light scattering data;

y_i : Represents the normalized value;

y_{min} : Represents the minimum value of light scattering data;

y_{max} : Represents the maximum value of the light scattering data;

4.

$$\hat{y} = \sum_{i=1}^N w_i \times y_i \quad (S7)$$

$$w_i = \frac{A_i}{\sum_{j=1}^N A_j} \quad (S8)$$

y_i : A single model predicts the outcome;

\hat{y} : Final prediction results;

w_i : Corresponding model weights;

A_i : The classification accuracy of the results of the corresponding model running on spectral data;

5.

$$Loss = -\sum_{i=1}^n y_k \log p_k \quad (S9)$$

$y_k, y_k \in \{0,1\}$, Represents a label of input data numbered k;

p_k : The predicted outcome of the sample;

Table S1 Main modules of elastic scattering spectrum acquisition device

Module	Parameter	Function	Manufacturer
Laser	wavelength: 633nm	Excitation light source	Shenzhen Fuzhe Technology Co., Ltd, China
Motorized turntable	resolution: 0.001°; repeatability accuracy: 0.01°	Fix and rotate the tissue sections	Beijing Yixuan Intelligent Control Technology Co., Ltd, China
Photodiode	response range: 400-1100nm	Collect elastic scattered light signals	Hamamatsu Photonics Co.,Ltd, Japan
IV conversion amplifier	supply voltage: $\pm 5V$ - $\pm 15V$ supply current: $\pm 30mA$	Convert and amplify output current of the photodiode to the voltage	Chengdu Kangwei Electronic Co., Ltd, China
Data acquisition cards	ADC resolution: 16 Bit; maximum sample rate: 50kS/s	Acquire the voltage signal output by the IV conversion amplifier	National Instruments Co., Ltd, USA
Main MCU	STM32F103	Control the movement of the motorized turntable	ST Microelectronics Co., Ltd
Power supply	output voltage: $\pm 5V$	Provide the voltage required by the system	Chengdu Kangwei Electronic Co., Ltd, China
PC Soft	DAQexpress	Displays data from the data acquisition card	National Instruments Co., Ltd, Switzerland

Table S2 Model training platform

Experimental platform	Parameter
operating system	Linux
Anaconda	23.7.4
Python	3.9.18
Pytorch	1.12.0
CUDA	12.3
GPU	NVIDIA RTX 3090
CPU	Intel Xeon Gold 6342
内存	251G
IDE	Pycharm 2023.3.5 (Professional Edition)

Table S3 Reference for Raman peak locations and molecular vibrational modes

Raman displacement (cm ⁻¹)	Peak attribution
721	Phospholipids in nucleic acids, C-N bonds in adenine, stretching vibration modes
758	Indole ring vibration mode of tryptophan
829	PO ₂ -asymmetric stretching mode in nucleic acids and tyrosine C-C bond stretching vibration mode
853	C-C stretching vibration mode of protein (collagen) or proline, serine and tyrosine
1004	C-C telescopic vibration mode of phenylalanine
1033	C-H plane bending vibration mode of aromatic compounds such as phenylalanine, tryptophan, tyrosine, etc
1088	PO ₂ -asymmetric stretching pattern of DNA or RNA
1127	Protein C-N bond stretching vibration mode; C-C telescopic vibration mode of lipids
1173	C-H planar bending vibration mode of phenylalanine, tyrosine
1338	CH ₂ CH ₃ telescopic vibration mode and CH ₂ CH ₃ bending vibration mode for proteins and nucleic acids; C-H planar bending vibration mode of unsaturated fatty acids for common olefins
1516	Stretching and contraction vibrations of C=C bonds of polyene chains in β -carotene molecules
1658	Amino compound I, α helix structure of proteins