

CLAIMS

[Claim 1]

A multi-capillary electrophoresis instrument comprising:

E (≥ 2) samples containing components labeled with G (≥ 2) fluorophores are injected into E capillaries and simultaneously electrophoresed in the E capillaries;

a laser-light source configured to irradiate measurement portions of the E capillaries disposed on the same plane with a laser beam; and

an optical system that receives fluorescences of the G fluorophores excited by the laser beam when the G fluorophores pass through the measurement portions, wherein

the optical system includes:

a spectroscopic element configured to respectively disperse the fluorescences emitted from the E capillaries into F (≥ 2 , $F \geq G$) predetermined wavelength bands; and

an image sensor having a plurality of two-dimensionally arranged pixels and configured to receive E $\times$ F dispersed fluorescences in E $\times$ F different bin regions on the image sensor,

the image sensor is configured to:

measure E $\times$ F signal intensities of the E $\times$ F dispersed fluorescences in the E $\times$ F bin regions; and

acquire time-series data of the E $\times$ F signal intensities by continuous repeated measurements at a predetermined exposure time and a predetermined time interval,

in a case where, in a bin region of any one of the E $\times$ F bin regions,

a number of pixels in the bin region is denoted by B_m (≥ 1),

the bin region is divided into B_s (≥ 1) hardware-binning regions,

an average number of pixels of the B_s hardware-binning regions is denoted by B_h (≥ 1),

$$B_m = B_h \times B_s,$$

a ratio of a maximum value of a saturation-light amount obtained by performing hardware binning to a saturation-light amount per single pixel of the image sensor is set as a saturation-light-amount ratio k (≥ 1),

a saturation-light-amount coefficient α is set to $\alpha = 1$ when $B_h = 1$, $\alpha = B_h$ when $1 < B_h < k$, and $\alpha = k$ when $k \leq B_h$, and $B_m = B_h = B_s = 1$,

total noise of the time-series data is classified into three components of readout noise of the image sensor, dark-current noise of the image sensor, and shot noise of background light, and

when the total noise is denoted by N , the readout noise is denoted by N_r , the dark-current noise is denoted by N_d , and the shot noise is denoted by N_s , and

a dark-current-noise ratio is represented by $b = N_d/N_r$ and a shot-noise ratio is represented by $c = N_s/N_r$,

B_m , B_h , B_s , k , α , b , and c satisfy a predetermined relationship.

[Claim 2]

The multi-capillary electrophoresis instrument according to claim 1, wherein

[Expression 1]

$$\frac{9 + \sqrt{81 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq (9 - B_m) \cdot b^2 + 8 \cdot c^2 + 9$$

is satisfied.

[Claim 3]

The multi-capillary electrophoresis instrument according to claim 2, wherein

$B_h = 1$, and

[Expression 2]

$$\frac{9 \cdot (b^2 + 1) + \sqrt{81 \cdot (b^2 + 1)^2 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq \frac{9 \cdot b^2 + 8 \cdot c^2 + 9}{b^2 + 1}$$

is satisfied.

[Claim 4]

The multi-capillary electrophoresis instrument according to claim 1, wherein

[Expression 3]

$$\begin{aligned} \frac{100 + \sqrt{10000 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} &\leq B_s \\ &\leq \frac{(9 - 4 \cdot B_m) \cdot b^2 + 5 \cdot c^2 + 9}{4} \end{aligned}$$

is satisfied.

[Claim 5]

The multi-capillary electrophoresis instrument according to claim 4, wherein

$B_h = 1$, and

[Expression 4]

$$\frac{100 \cdot (b^2 + 1) + \sqrt{10000 \cdot (b^2 + 1)^2 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s$$
$$\leq \frac{9 \cdot b^2 + 5 \cdot c^2 + 9}{4 \cdot (b^2 + 1)}$$

is satisfied.

[Claim 6]

The multi-capillary electrophoresis instrument according to claim 1, wherein

$c \geq 2.5$,

$B_h = 1$, and

$4 \leq B_s \leq 59$

are satisfied.

[Claim 7]

The multi-capillary electrophoresis instrument according to claim 1, wherein

$c \geq 10$,

$B_h = 1$, and

$3 \leq B_s \leq 809$

are satisfied.

[Claim 8]

The multi-capillary electrophoresis instrument according to claim 7, wherein

$c \geq 10$,

$B_h = 1$, and

$11 \leq B_s \leq 127$

are satisfied.

[Claim 9]

A multi-capillary electrophoresis instrument comprising:

E (≥ 2) samples containing components labeled with G (≥ 2)

fluorophores are injected into E capillaries and simultaneously electrophoresed in the E capillaries;

a laser-light source configured to irradiate measurement portions of the E capillaries disposed on the same plane with a laser beam; and

an optical system that receives fluorescences of the G fluorophores excited by the laser beam when the G fluorophores pass through the measurement portions, wherein

the optical system includes:

a spectroscopic element configured to respectively disperse the fluorescences emitted from the E capillaries into F (≥ 2 , $F \geq G$) predetermined wavelength bands; and

an image sensor having a plurality of two-dimensionally arranged pixels and configured to receive $E \times F$ dispersed fluorescences in $E \times F$ different bin regions on the image sensor,

the image sensor is configured to:

measure $E \times F$ signal intensities of the $E \times F$ dispersed fluorescences in the $E \times F$ bin regions;

when any one fluorophore of the G fluorophores emits fluorescence from the measurement portion of any one capillary of the E capillaries,

derive F normalized signal intensities by normalizing the F signal intensities in the F bin regions for the one capillary so that a maximum value of the F signal intensities becomes 1;

set a merged-bin region that merges bin regions having the normalized signal intensity of 0.5 or more among the F normalized signal intensities and derive a merged-signal intensity in the merged-bin region; and

assume to acquire time-series data of a merged-signal intensity in the merged-bin region by continuous repeated measurements at a predetermined exposure time and a predetermined time interval,

a number of pixels in the merged-bin region is denoted by B_m (≥ 1),

the merged-bin region is divided into B_s (≥ 1) hardware-binning regions,

an average number of pixels of the B_s hardware-binning regions is denoted by B_h (≥ 1),

$$B_m = B_h \times B_s,$$

a ratio of a maximum value of a saturation-light amount obtained by performing hardware binning to a saturation-light amount per single pixel of the image sensor is set as a saturation-light-amount ratio k (≥ 1),

a saturation-light-amount coefficient α is set to $\alpha = 1$ when $B_h = 1$, $\alpha = B_h$ when $1 < B_h < k$, and $\alpha = k$ when $k \leq B_h$, and when $B_m = B_h = B_s = 1$,

total noise of the time-series data is classified into three components of readout noise of the image sensor, dark-current noise of the image sensor, and shot noise of background light, and

the total noise is denoted by N , the readout noise is denoted by N_r , the dark-current noise is denoted by N_d , and the shot noise is denoted by N_s , and

a dark-current-noise ratio is represented by $b = N_d/N_r$ and a shot-noise ratio is represented by $c = N_s/N_r$,

B_m , B_h , B_s , k , α , b , and c satisfy a predetermined relationship.

[Claim 10]

The multi-capillary electrophoresis instrument according to claim 9, wherein

[Expression 5]

$$\frac{9 + \sqrt{81 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq (9 - B_m) \cdot b^2 + 8 \cdot c^2 + 9$$

is satisfied.

[Claim 11]

The multi-capillary electrophoresis instrument according to claim 10, wherein

$B_h = 1$, and

[Expression 6]

$$\frac{9 \cdot (b^2 + 1) + \sqrt{81 \cdot (b^2 + 1)^2 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq \frac{9 \cdot b^2 + 8 \cdot c^2 + 9}{b^2 + 1}$$

is satisfied.

[Claim 12]

The multi-capillary electrophoresis instrument according to claim 9, wherein

[Expression 7]

$$\frac{100 + \sqrt{10000 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s$$
$$\leq \frac{(9 - 4 \cdot B_m) \cdot b^2 + 5 \cdot c^2 + 9}{4}$$

is satisfied.

[Claim 13]

The multi-capillary electrophoresis instrument according to claim 12, wherein

$B_h = 1$, and

[Expression 8]

$$\frac{100 \cdot (b^2 + 1) + \sqrt{10000 \cdot (b^2 + 1)^2 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s$$
$$\leq \frac{9 \cdot b^2 + 5 \cdot c^2 + 9}{4 \cdot (b^2 + 1)}$$

is satisfied.

[Claim 14]

A multi-capillary electrophoresis instrument comprising:

E (≥ 2) samples containing components labeled with G (≥ 2) fluorophores are injected into E capillaries and simultaneously electrophoresed in the E capillaries;

a laser-light source configured to irradiate measurement portions of the E capillaries disposed on the same plane with a laser beam; and

an optical system that receives fluorescences of the G fluorophores excited by the laser beam when the G fluorophores pass through the measurement portions, wherein

the optical system includes:

a spectroscopic element configured to respectively disperse the fluorescences emitted from the E capillaries into F (≥ 2 , $F \geq G$) predetermined wavelength bands; and

an image sensor having a plurality of two-dimensionally arranged pixels and configured to receive E $\times$ F dispersed fluorescences in E $\times$ F different bin regions on the image sensor,

the image sensor is configured to:

measure E $\times$ F signal intensities of the E $\times$ F dispersed fluorescences in the E $\times$ F bin regions;

acquire first time-series data of the $E \times F$ signal intensities by continuous repeated measurements at a predetermined exposure time and a predetermined time interval; and

derive second time-series data of $E \times G$ concentrations of the G fluorophores at the measurement portions of the E capillaries by calculation using the first time-series data,

when any one fluorophore of the G fluorophores emits fluorescence from the measurement portion of any one capillary of the E capillaries, and

in a case where XR is a ratio of a maximum value of the concentrations of the G fluorophores at the measurement portions of the E capillaries excluding the one capillary to the concentration of the one fluorophore at the measurement portion of the one capillary,

in a bin region of any one of the $E \times F$ bin regions, a number of pixels in the bin region is denoted by B_m (≥ 1),

the bin region is divided into B_s (≥ 1) hardware-binning regions,

an average number of pixels of the B_s hardware-binning regions is denoted by B_h (≥ 1),

$$B_m = B_h \times B_s,$$

a ratio of a maximum value of a saturation-light amount obtained by performing hardware binning to a saturation-light amount per single pixel of the image sensor is set as a saturation-light-amount ratio k (≥ 1),

a saturation-light-amount coefficient α is set to $\alpha = 1$ when $B_h = 1$, $\alpha = B_h$ when $1 < B_h < k$, and $\alpha = k$ when $k \leq B_h$, and

$$B_m = B_h = B_s = 1,$$

total noise of the first time-series data is classified into three components of readout noise of the image sensor, dark-current noise of the image sensor, and shot noise of background light, and

when the total noise is denoted by N , the readout noise is denoted by N_r , the dark-current noise is denoted by N_d , and the shot noise is denoted by N_s , and

a dark-current-noise ratio is represented by $b = N_d/N_r$ and a shot-noise ratio is represented by $c = N_s/N_r$,

XR, B_m , B_h , B_s , k , α , b , and c satisfy a predetermined relationship.

[Claim 15]

The multi-capillary electrophoresis instrument according to claim 14, wherein

$$XR \leq 10^{-3}, \text{ and}$$

[Expression 9]

$$\frac{9 + \sqrt{81 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq (9 - B_m) \cdot b^2 + 8 \cdot c^2 + 9$$

is satisfied.

[Claim 16]

The multi-capillary electrophoresis instrument according to claim 15, wherein

$$B_h = 1, \text{ and}$$

[Expression 10]

$$\frac{9 \cdot (b^2 + 1) + \sqrt{81 \cdot (b^2 + 1)^2 + 36 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s \leq \frac{9 \cdot b^2 + 8 \cdot c^2 + 9}{b^2 + 1}$$

is satisfied.

[Claim 17]

The multi-capillary electrophoresis instrument according to claim 14, wherein

$$XR \leq 10^{-3}, \text{ and}$$

[Expression 11]

$$\begin{aligned} \frac{100 + \sqrt{10000 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot (B_m \cdot b^2 + c^2)}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} &\leq B_s \\ &\leq \frac{(9 - 4 \cdot B_m) \cdot b^2 + 5 \cdot c^2 + 9}{4} \end{aligned}$$

is satisfied.

[Claim 18]

The multi-capillary electrophoresis instrument according to claim 17, wherein

$$B_h = 1, \text{ and}$$

[Expression 12]

$$\frac{100 \cdot (b^2 + 1) + \sqrt{10000 \cdot (b^2 + 1)^2 + 400 \cdot \alpha^2 \cdot (b^2 + c^2 + 1) \cdot c^2}}{2 \cdot \alpha^2 \cdot (b^2 + c^2 + 1)} \leq B_s$$

$$\leq \frac{9 \cdot b^2 + 5 \cdot c^2 + 9}{4 \cdot (b^2 + 1)}$$

is satisfied.

[Claim 19]

A multi-capillary electrophoresis instrument comprising:

E (≥ 2) samples containing components labeled with G (≥ 2) fluorophores are injected into E capillaries and simultaneously electrophoresed in the E capillaries;

a laser-light source configured to irradiate measurement portions of the E capillaries disposed on the same plane with a laser beam;

an optical system that receives fluorescences of the G fluorophores excited by the laser beam when the G fluorophores pass through the measurement portions; and

a computer configured to control the instrument, wherein the optical system includes:

a spectroscopic element configured to respectively disperse the fluorescences emitted from the E capillaries into F (≥ 2 , $F \geq G$) predetermined wavelength bands; and

an image sensor having a plurality of two-dimensionally arranged pixels and configured to receive $E \times F$ dispersed fluorescences in $E \times F$ different bin regions on the image sensor,

the image sensor is configured to:

measure $E \times F$ signal intensities of the $E \times F$ dispersed fluorescences in the $E \times F$ bin regions; and

acquire time-series data of the $E \times F$ signal intensities by continuous repeated measurements at a predetermined exposure time and a predetermined time interval,

in a case where, in a bin region of any one of the $E \times F$ bin regions,

a number of pixels in the bin region is denoted by B_m (≥ 1),

the bin region is divided into B_s (≥ 1) hardware-binning regions,

an average number of pixels of the hardware-binning regions is denoted by B_h (≥ 1),

$$B_m = B_h \times B_s,$$

a ratio of a maximum value of a saturation-light amount obtained by performing hardware binning to a saturation-light amount per single pixel of the image sensor is set as a saturation-light-amount ratio k (≥ 1),

a saturation-light-amount coefficient α is set to $\alpha = 1$ when $B_h = 1$, $\alpha = B_h$ when $1 < B_h < k$, and $\alpha = k$ when $k \leq B_h$, and

$$B_m = B_h = B_s = 1,$$

total noise of the time-series data is classified into three components of readout noise of the image sensor, dark-current noise of the image sensor, and shot noise of background light, and

when the total noise is denoted by N , the readout noise is denoted by N_r , the dark-current noise is denoted by N_d , and the shot noise is denoted by N_s , and

a dark-current-noise ratio is represented by $b = N_d/N_r$ and a shot-noise ratio is represented by $c = N_s/N_r$,

a plurality of types of predetermined relationships satisfied by B_m , B_h , B_s , k , α , b , and c are provided, and

the computer is configured to provide an environment in which a desired predetermined relationship can be selected from among the plurality of types of predetermined relationships.

[Claim 20]

The multi-capillary electrophoresis instrument according to claim 19, wherein

the computer provides a user interface that allows a user to select the desired predetermined relationship.